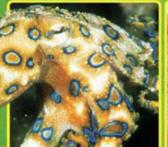


How could ultra-cold cryogenic tech help you live forever?

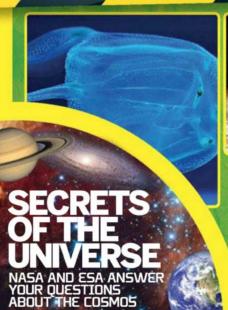








ENOM HOW THE WORLD'S MOST TOXIC ANIMALS KILL





TREME MOTORSPORT

Discover the engineering that fuels high-octane race vehicles from NASCAR to Le Mans

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- **PHOTONS**

- TREE ANATOMY VENUS LANDINGS
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- FLARE GUNS QUARTZ CLOCKS
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The magazine that feeds minds! ISSUE 31

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Find out more about the experts behind your favourite articles in this issue's edition of **How It Works**...

Dave Roos





turns his hand – n literally, of course, that would be foolish – to the planet's most deadly creatures and how they kill with venom.

Rik Sargent



Shaun McGill



devices for many years. His feature reveals the tech we'll be enjoying in the very near future

Dave Howell Quartz clocks



Technology writer
Dave authored a
number of articles
on essential
domestic devices in
this issue of How It
Works, including smart electricity
meters, baby monitors, heart-rate
machines and quartz clocks.

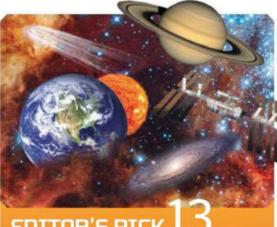
Alasdair Stuart



Hitting up the How It Works Transport section this issue, Alasdair Stuart reveals how chain ferries and tugboats work as well as how mechanics repair chipped windscreens.

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"FEED YOUR MIND



THE SECTIONS EXPLAINED

The huge amount of info in each issue of How It Works is organised into these sections

The splendour of the natural world explained

Be it road, rail, air or sea, you'll find out about it in the transport section

Explaining the applications of science in the contemporary world around us



Your questions worked in the pastanswered

TECHNOLOGY

The wonders of modern gadgetry and engineering explained

From exploration ofoursolar system to deepspace adventures



HOW TO DECIPHER YOUR OR CODE...

This black and white matrix barcode is what's known as a QR code and in it we've concealed a random - but nonetheless intriguing - fact for you. To decode this message you'll need to download a QR code reader app on to your mobile phone. Then simply view the code through the camera screen and the secret message will appear.

With thanks How It Works would like to thank the following organisations for their help













Of all nature's remarkable predators, those with the ability to outsmart and overcome their prevusing methods other than sheer size and brute strength are undoubtedly among the most compelling to learn about. Of course, big ferocious bears and sharp-toothed sharks are impressive killers, but that kind of approach to hunting is so, well, obvious.

This issue's 'Science of venom' feature looks instead at the variety of species blessed with toxic fangs, stings and even those whose very skin oozes noxious substances.

We've all been warned about the brightly coloured specimens that are not safe to handle - indeed, you can tell from their psychedelic appearance that they're just waiting to pump you full of a lethal cocktail of chemicals - and so we tend to give them a wide berth. But what of those creatures that look harmless - or even cuddly? Turn to page 44 for our guide to the most venomous creatures on the planet. Discover the tactics they use, find out what's in the fatal fluids that they secrete and, ultimately, learn which beasties to avoid at all costs.

Also this issue we are ecstatic to announce the launch of our incredible new How It Works Daily website, which you can learn more about on page 11. Check it out today.

Enjoy the issue.



Helen Laidlaw

Meet the team...



Dave Ed in Chief

The max power racers feature packed a mighty punch this issue, I learned so many new things and the machines involved are just incredible. I also



all those involved. And

sent in their questions.

thanks to the readers who



Robert Senior Staff Writer

Now, I'm an F1 fan but having discovered four other of the world's most nsane racing events in the 'Extreme motorsport' feature. I now realise that for pure racing action, we should look elsewhere.



Adam Senior Sub Editor

My favourite read this issue was definitely the fascinating field of cryogenics and the secrets of freezing. That said, my dad's a refrigeration engineer, so might be a bit biased!

ISSUE 31 The magazine that feeds minds!

6 Global Eye

Get the latest news and the greatest stories from the world of science, technology and the environment.



SPECIAL FEATURE

Secrets of the cosmos

A panel of NASA and ESA experts help answer 75 of our readers' questions about astronomy and the universe

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Discover how these stealthy birds of prey hunt in the wild and whether they're as wise as they're made out to be

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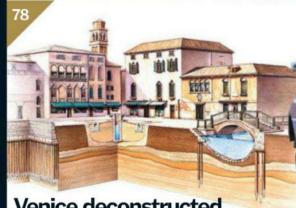
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The one and so far only vessel to descend to the deepest point in Earth's oceans: the Challenger Deep

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How was this floating city constructed?





Venice deconstructed

The City of Canals is famed for its gondolas and carnival, but how exactly was it built?

80 Expert answers Scientists from the finest museums in the world answer your questions in this issue's jam-packed Brain dump



Caroline Warhurst The information services manager at London Transport Museum, Caroline is here to answer all your transport-related questions this issue.



Andrew Brooks Andrew loves thinking about all the planets that exist across the universe. When not explaining at the Museum he likes making lots of noise on the drums.



Aidan Dodson Aidan teaches Egyptology at the University of Bristol. He's the advisor for the Fascinating Mummies exhibition at the National Museum of Scotland now.





Stunning hi-def image of Earth revealed

NASA celebrates the 40th anniversary of the famous 'Blue Marble' image of our planet by releasing an updated, high-fidelity version

NASA has unveiled a spectacular highdefinition version of its famous 'Blue Marble' image of Earth. The stunning shot comes 40 years after the original was taken on board the Apollo 17 spacecraft at a distance of 45,062 kilometres (28,000 miles) from our blue planet. It was taken by NASA's latest Earth observation satellite, Suomi NPP, which launched in October 2011

The image itself, interestingly, is a composite of many shots which were captured by the Suomi NPP's visible/infrared imager radiometer suite (VIIRS), a scanning telescope that measures the difference between the amount of light coming down to the surface of Earth from the Sun as compared to the amount of light that is reflected back to the telescope. As such, the image you can see here on this page is the result of multiple 3,058-kilometre (1,900-mile)-wide 'smaller' snaps being pieced together to form one seamless picture.

This stitching together of images is possible because the Suomi NPP is currently on a Sun-synchronous orbit; this means that the satellite crosses the equator at the same time each orbit (currently 14 times a day) which allows for an evenly lit and consistent final image.

Despite the awesome fidelity and beauty of the 2012 Blue Marble, the Suomi NPP's work is only just beginning. The satellite, which weighs 2,100kg (4,600lb) and is the size of a small bus, will now spend the next decade observing the Earth and gathering a host of data. This information will include temperature and pressure patterns, ozone levels – especially near the poles, ice and landform movements and emitted thermal radiation.

The satellite was named Suomi NPP on 24 January 2012 in honour of Verner E Suomi, who died in 1995. The American meteorologist is generally considered the father of satellite meteorology.







HMS Victory 'to be recovered' from ocean floor

The remains of a predecessor to Admiral Nelson's famous flagship are to be raised from the seabed, along with an estimated £500 million in gold coins

HMS Victory, a 300-year-old warship that was lost in a storm during 1744, is to be hauled up from its resting place after 268 years. The ship, which cost the Royal Navy the lives of over a thousand sailors when it sank, is believed to contain gold coins worth an estimated £500 (\$788) million.

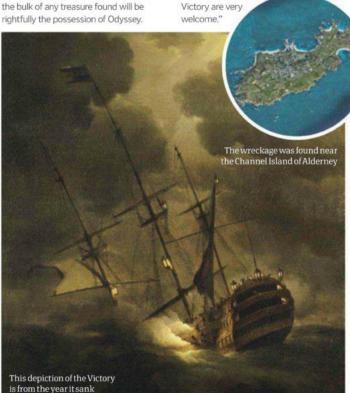
The wreckage was found four years ago near the island of Alderney in the English Channel by American company Odyssey Marine Exploration, and was confirmed shortly after by the analysis of an ancient bronze cannon from the site.

According to *The Sunday Times* newspaper, the gun, along with a selection of other surviving artefacts, will go on display throughout Britain in naval museums once they're recovered. However, under the UK laws of salvage, the bulk of any treasure found will be rightfully the possession of Odyssey.

Built in 1737, HMS Victory was the principal ship of the age, constructed by master shipwright Joseph Allin and acting as the flagship for the Royal Navy's Channel Fleet under the command of Sir John Norris. The story of the ship's vast on-board wealth – which was the result of trading and raiding enemy ships – originates from a financial publication released a month after it sank, which stated that 'people will have it that on board of the Victory was a sum of 400,000 pounds sterling that it had brought from Lisbon for our merchants.'

Speaking on the announcement that HMS Victory was to be raised from the seabed, a Ministry of Defence source said that any "efforts to protect key parts of British naval history such as the 1744 wreck of HMS

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THIS DAY IN HISTORY 23 FEBRUARY: How It Works issue 31 goes on sale, but what

The Roman Emperor Diocletian begins eight years of persecution against Christians by destroying a church in Nicomedia, Turkey.



1455 The Gutenberg Bible is printed for the first time in Germany. It is the first Western book to be printed with movable type.

1739 Aretired schoolteacher identifies the notorious highwayman Dick Turpin as John Palmer. The criminal had been a former school pupil of his.

1836
The famous
Battle of the
Alamo begins
in San Antonio



1945

a magnetically harmonised way.

One of the most iconic photos of the Second World War is taken as soldiers raise the American flag on the Japanese island of Iwo Jima.

plate, causes normal field instability and allows the fluid to overcome gravity, spiking upwards in

> 1958 Cuban rebels kidnap five-time world driving champion, Juan

Manuel Fangio.

WorldMags.net



Bovington Tankfest 2012

The tenth anniversary of the world's biggest and best tank festival promises to blow the lid off your expectations with a battalion-load of explosive action over two days



Fancy watching some of mankind's most awesome armoured vehicles delivering

demonstrations of their deadly prowess live? Well, if so, the Bovington Tank Museum's annual Tankfest extravaganza in Dorset is one event you should mark in your calendar. With heavy metal operating throughout the weekend of 30 June to 1 July in the Tank Museum Arena, a fantastic selection of trade stalls supplying refreshments and souvenirs, a range of educational living-history encampments

to explore, as well as a series of special events in the Museum itself, 2012's festival is set to be the largest yet.

Indeed, this year will see the Museum's World War I Mk IV replica tank – built for the film War Horse – in action for the first time, along with the famous World War II Tiger tank and a selection of modern British Army vehicles including the Challenger 2. So, what are you waiting for? For up to 20 hours of non-stop tank mayhem head to www.tankmuseum.org for tickets and more information.



Mutant flu virus sparks fear of pandemic

US government restricts publication of research detailing creation of mutant strains of the H5N1 avian influenza virus



The US government – with co-operation from the revered scientific journals *Nature* and

Science – has restricted the publication of research detailing the creation of multiple mutant strains of the deadly H5N1 avian influenza virus amid fears of potential outbreaks and bioterrorism.

Currently, the mutant strains are contained within mandatory level 3 (BSL-3) containment facilities, but amid the current controversy engulfing the international bioscience community regarding the projects, many scientists are arguing that due to their extreme danger the strains, as well as research into them, should be kept within level 4 laboratories (BSL-4) that have the highest biosafety rating.

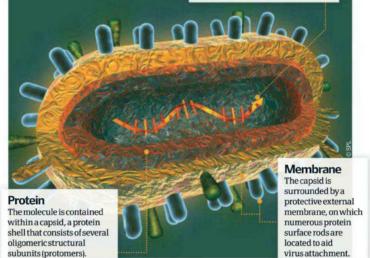
The mutant strains, if released, would spread as quickly as ordinary flu, yet deliver a fatality rate akin to wild-type H5N1, which in 2005 led to nearly 1.2 million birds to be slaughtered in Vietnam to contain an outbreak.

Further, under mounting pressure by international governments and institutions, a 60-day suspension into mutant flu research has been called for. Writing in a statement published on 20 January, many scientists warn that "organisations and governments need time to find the best solutions for opportunities and challenges that stem from the work." However, some scientists believe the research shouldn't continue at all. Richard Ebright, a molecular biologist and biodefence expert at Rutgers University, addressing people's fears, stated: "In the US, there is only voluntary oversight for biosafety, and with the exception of the select agents rule, there is no oversight of biosecurity. What's remarkable [is that for research of this type], which puts at risk not one individual but potentially hundreds, thousands or millions, there is no oversight whatsoever."

It's hoped that the called-for pause in research will provide enough time to weigh up the pros and cons of this research going forward.

Molecule

The virus's core comprises a single-stranded RNA molecule, which contains its genetic material.



else happened on this day in history?



Supernova 1987a is seen in the Large

1997

A fire breaks out on the Russian space station Mir. No crew-members are harmed.



1000

An avalanche destroys the Austrian village of Galtür located in the southern Tyrol region. 31 people are killed.

2010 Unidentified criminals pour more than 2.5m litres (660,430 gallons) of diesel into the River Lambro, northern Italy, causing an

environmental disaster.



GLQBAL EYENEWS

THINGS WE'VE LEARNED THIS

MONTH



1 Smallest frog lives in New Guinea

Researchers in the United States have announced they have discovered the smallest frog in the world, which may also hold the record of smallest vertebrate. Measuring a tiny seven millimetres (0.27 inches) in length, the frog known as paedophryne amauensis is no bigger than a US dime. The frog was found in the forests of New Guinea, Indonesia, although its minute size and calls, imitating that of insects,

2 Every star has planets

made it tricky to locate.

A study released at the 219th American Astronomical Society (AAS) meeting suggests that every star in the universe plays host to at least one planet. Using a technique called gravitational microlensing, the researchers studied a variety of exoplanets in orbit around stars and estimated that one or several planets must be in orbit around every star.

3 Rats are friendly creatures

Going against the popular conception that rats are nasty animals, a study in the journal *Science* suggests these oft-maligned mammals are actually rather amiable. The team of researchers placed one rat in a cage, with an external safety release, and left another free to roam outside. Eventually, admittedly after seven

days, the free rat found out how to release his trapped companion. If there was no rat inside the cage, or it was replaced with a stuffed animal, the free rat showed little or no desire to free his comrade.

4 Memory storage is getting smaller

Scientists at IBM and the
German Center for FreeElectron Laser Science
(CFEL) have created the
world's smallest magnetic
data storage device. Using
a scanning tunnelling
microscope (STM) at IBM's
Almaden Research Center in
San Jose, California, the team
constructed a nanometre-sized device

constructed a nanometre-sized device that fits a whole byte of information into just 96 atoms; that means you could fit an entire gigabyte into a full stop.

5 The longest experiment in the world is... ongoing

In 1930, Professor of Physics at the University of Queensland, Thomas Parnell, began an experiment to show how a material called pitch, which is a derivative of tar, demonstrates signs of viscosity despite being solid and brittle when kept at room temperature. A sample of pitch was placed in a funnel at room temperature inside a container and, ever since, it has been left to slowly move through the funnel. In over 80 years it has dripped just eight times, giving it a viscosity 100 billion times that of water.

6 Monster jet will launch rockets

Planning for the world's largest plane - the Stratolaunch Systems carrier aircraft - has begun, boasting the possibility of firing rockets and satellites into orbit at cut price. Stratolaunch Systems is a new space venture sponsored by Microsoft co-founder Paul Allen. The giant plane, which will be assembled from recycled 747 airliners, aims to take rockets high into the stratosphere and launch them into space, allowing satellites to be taken into orbit at cheaper prices. The massive hangar in California required to build the plane is expected to be finished in late-2012, with the plane scheduled to make its first test flight in 2015.

7 Magnetic soap could clean oil

Details of a new soap that could lessen the environmental impact of oil spills have been published in the chemistry journal Angewandte Chemie. The soap is infused with iron, making it magnetic and allowing it to be removed by a magnetic field. As soap naturally sticks to oily substances, the team of researchers at the University of Bristol say this new magnetic detergent could be used to clean up oil spills.

8 Dogs are truly our oldest friends

In the Altai Mountains of Siberia, researchers have found a 33,000-year-old dog skull that shows clear signs of domestication, including a shortened snout and crowded teeth, suggesting dogs have been man's best friend for quite some time. It's believed that dogs would have been useful hunting partners for ancient humans, in addition to providing companionship as they do today. The discovery of similar remains around the world points to an almost-simultaneous domestication of dogs in many areas.

9 Phones could monitor our health

A team of scientists at Korea's Advanced Institute of Science and Technology (KAIST) have suggested the touchscreens on smartphones could be used to detect biomolecular matter, potentially enabling future phones to diagnose us with anything from a common cold to more serious ailments. The research showed that DNA molecules from a person's finger placed on a touchscreen could be recognised by built-in technology, allowing people to perform instant self-diagnoses.

10 Crumpled paper is fascinating

Our most bizarre story this month involves crushed paper. Scientists at the University of Massachusetts have been studying crumpled paper balls to try and ascertain why they are so strong and complex. In their research they found that no matter how hard you squash paper, it's almost impossible to make a structure composed of less than 90 per cent air. Additionally, no computer is powerful enough to create an exact replica of a paper ball; the shapes and folds involved are just too complex.

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How It Works launches awesome new supersite

Your favourite magazine's website has just been catapulted into the future with a fantastic redesign and loads of top new content

That's right, it's here! How It Works is kicking off 2012 with a phenomenal redesign of its website, offering readers a wall of knowledge from which to feed their insatiable hunger for facts.

The site, which is live right now, has been specially created to deliver our vast archive of knowledge in the easiest and most fun way ever, giving you immediate access to all of your magazine favourites such as articles, Q&As, top five facts, reviews, news

and interviews. In addition, however, the new site also boasts a host of brand-spanking new material and features such as fully interactive illustrations and cutaways, as well as enhanced social-media integration and interactive guizzes.

So, what are you waiting for? For once put down your copy of How It Works and head to www.howitworksdaily.com for a little taste of a bright and knowledgeable future.

Readers' questions

For Brain dump lovers, explore our entire archive of juicy facts and answers in the Q&A section.







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understanding and knowledge of the wider universe,

With that in mind, we've assembled a team of

space largely remains a cosmic mystery with so many

experts from NASA, the ESA and beyond to answer 75

questions submitted by you, the readers. Over the next

eight pages you'll uncover a wide array of fascinating

facts, in addition to learning more about some of the

THE EXPERTS



Wesley Traub Chief scientist for NASA's Exoplanet Exploration

despite making these giant strides in our

The next decade will be the most thrilling era of space

exploration and astronomy in the history of mankind -

technology over the past 50 years have enabled us to

study and explore the cosmos like never before, from

sending probes into deep space to gazing at distant

exoplanets that could potentially harbour life. However,

and that's no overstatement. Great advances in



Michael Khan Spacecraft engineer and mission analyst



Klaas
Wiersema
Postdoctoral
researcher at th
University of
Leicester, UK.

questions still unanswered.



Somak Raychaudhury Astrophysics lecturer at the University of Birmingham, UK



Harry Cliff
Particle physicist
at CERN and the
first Science
Museum Fellow of
Modern Science.

these questions and many more.



most bizarre phenomena that the universe has to offer.

Was the first animal in space a dog or a bug? Could you fly a spacecraft through Jupiter? Will space travel for

the common man become a reality in our lifetime? Is it

certain that we'll find alien life, and will we ever travel to one of the Earth-like planets discovered outside our

solar system? Read on to find out the answers to all

Jonny O'Callaghan Resident space expert on How It

WorldMags.net

HOW IT WORKS

WHICH PLANET HAS THE MOST MOONS?

1 Jupiter has the most moons, with 64 confirmed and possibly more undiscovered. From the inner solar system outwards, Mercury and Venus have no moons, Earth has one, Mars has two, Jupiter has 64, Saturn has 62, Uranus has 27, Neptune has 13 and Pluto has four - the only dwarf planet to have any natural satellites. HIW

IS PLANET X REAL?

Planet X, or Nibiru, is a hypothetical planet in the solar system that conspiracy theorists suggest will crash into Earth at the end of 2012. However, there is absolutely zero evidence that it exists. A body of this size on a collision course with Earth would be easily detectable from a great distance. HIW

HOW WIDE ARE SATURN'S RINGS?

First observed by Galileo Galilei back in 1610, the rings of Saturn extend from 7,000 kilometres (4,350 miles) above its surface to 80,000 kilometres (49,710 miles) out into space. HIW

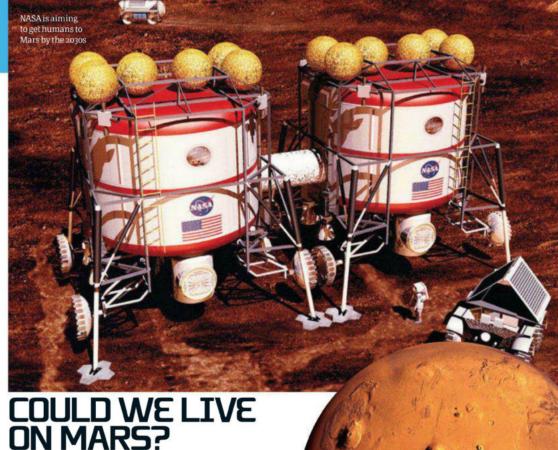
WHAT IS THE LONGEST AN ASTRONAUT HAS BEEN IN SPACE?

The record for the longest continuous time in space is held by Russian cosmonaut Valeri Polyakov, who spent 437.7 days on board Mir in 1994-95. The record for longest non-continuous time in space belongs to cosmonaut Sergei Krikalev who spent 803 days in space on board Soyuz, the Space Shuttle, Mir and the International Space Station (ISS), HIW



WHAT WAS THE TOP SPEED OF THE LUNAR ROVER ON THE MOON?

Lunar roving vehicles (LRVs) were used on the Apollo 15, 16 and 17 missions. Each of the vehicles had an estimated top speed of 13 kilometres (eight miles) per hour. However, NASA astronaut Eugene Cernan set the unofficial lunar land speed record in 1972 during the Apollo 17 mission, reaching 18 kilometres (11.2 miles) per hour, HIW



Mars offers a lot of the raw materials that humans need for survival but not all. We would need an airtight habitat that protects its occupants from radiation and meteorites and keeps the thin, unbreathable Mars atmosphere out and maintains Earth-like conditions inside. Much of the habitat and its consumables could be manufactured from materials available on Mars. Mars's gravity is 38 per cent of what we experience on Earth, which would take some getting used to but would still allow humans to live comfortably. However, a manned base on Mars would require constant supply ships from Earth to bring food and other resources that the Red Planet does not have. MICHAEL KHAN

This is an old chestnut first pondered by Thomas Digges in the 16th century. He considered a universe that was infinitely large, infinitely old and filled evenly with stars. If our universe were like that then the night skywould be as bright as the surface of the Sun - everywhere you looked you would see a star. This problem was finally resolved by the discovery that space is expanding, stretching light as it travels, shifting it from high to low energy. The further away a star is, the more the light from it has been stretched and the dimmer it. appears, making the sky between nearby stars appear black. HARRY CLIFF

storm has been raging for centurie

WHY DOESN'T JUPITER'S 'RED SPOT' STORM EVER DISPERSE?

Jupiter's great red spot is a vast storm system. We don't know that it doesn't ever disperse as Jupiter has been observed through telescopes for only 402 years. In that time, the great red spot has fluctuated in size, but not disappeared. We don't know how long it has existed, and we don't know how long it will be there. Currently it appears to be shrinking, but that might well change again. MICHAEL KHAN

IS THERE WATER ON

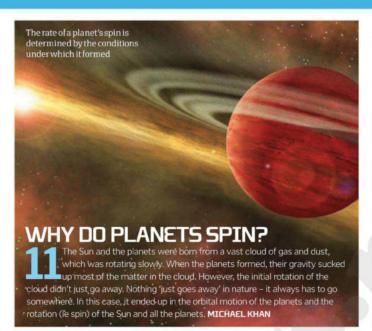
There's definitely ice on Mars, which has been directly observed at the poles and elsewhere. However, evidence from NASA's Mars rovers and the Mars Reconnaissance Orbiter (MRO) suggests that beneath Mars's surface is also liquid water, but upon exposure to the air it evaporates. It's estimated that we'll need to drill several metres below the surface to find this liquid water. Gullies on Mars also indicate water once existed here, and may still do today. These may have formed due to a large quantity of ice melting under its own pressure, forming liquid water that could flow briefly before evaporating. JONNY O'CALLAGHAN

SECRETS OF THE UNIVERSE

WHY IS VENUS HOTTER THAN MERCURY?

Mercury has no atmosphere. Heat from the Sun reaches the surface and heats up the rocky land, which then radiates heat back into space. It does get very hot on Mercury at the spot where the Sun is directly overhead but at the poles it is much cooler and the 'night' side is very cold. Conversely, Venus has a thick atmosphere made up of carbon dioxide, so there is a strong greenhouse effect.

Though Venus is farther from the Sun and therefore less intense sunshine reaches it, much of the heat gets trapped in the super-dense atmosphere. As a result, Venus is consistently very hot all over its surface. MICHAEL KHAN



IS THE UNIVERSE EXPANDING?

When astronomers look deep into space distant galaxies appear to be zooming away from us, and the further away they are the faster they are receding. But in fact, these galaxies aren't moving in the traditional sense. Instead the space itself between them and us is expanding. However, the universe isn't expanding into anything; as far as we know, the expansion is an intrinsic property of space itself. No one knows what the eventual fate of the universe will be. HARRY CLIFF



HOW DO YOU EXTINGUISH A FIRE ON THE ISS?

In the event of a fire on the station, the crew will first shut down power in the affected area and then turn off the ventilation system to starve the fire of oxygen. If it continues to burn they have portable carbon dioxide extinguishers to put it out.

WHAT IS SPACE SICKNESS?

15 On Earth we analyse our surroundings predominantly with our eyes and ears to balance. However, in space your audio receptors are rendered useless, so you must rely on vision alone. This can be disconcerting during the first few months in space and can often lead to a bout of nasty nausea. HIW

WHAT IS THE LARGEST STAR EVER FOUND?

The biggest star we know of in the universe is a red supergiant called VY Canis Majoris. Located in the constellation Canis Major 4,900 light years from Earth, it is up to 2,100 times bigger than our Sun. Massive red supergiants like this are commonly called hypergiants. To find out more about these huge stars, head to page 64. HIW



WHAT WAS THE FIRST ANIMAL IN SPACE?

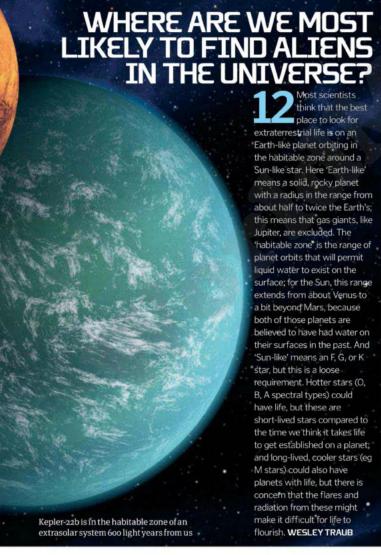
17 The first animals to be sent into space were fruit flies on board a US V2 rocket on 20 February 1947. The first mammal in space was the rhesus monkey Albert II on 14 June 1949, while the first animal to orbit Earth was the Russian dog Laika on 3 November 1957. HIW

COULD THE MOON EVER BE KNOCKED OUT OF ORBIT?

18 To be stopped the moon would have to be struck by a force at least equal to its kinetic energy (half its mass times its velocity squared). With a mass of 7.3 x 10²² and a velocity of about 1,000 metres (3,280 feet) per second, this is roughly equivalent to 10 trillion megatons of TNT. Nothing on Earth or in the solar system has this necessary force to dislodge the moon. **HIW**

WHY DO SOME PLANETS HAVE RINGS?

19 There are two theories as to why planets have rings. The first suggests that material orbiting too close to a planet like Saturn would be unable to form into a moon early in its life, instead forming rings of debris. The other theory is that an impact that takes place near a planet could create debris which remains trapped in its orbit. HIW



HOW IT WORKS

WHY DO MOONS FORM?

20 Moons form early in a planet's life cycle when space-faring rocks either crashed into the planet and threw off debris or became ensnared by the planet's gravitational pull. The rocks and dust were gradually squashed into a spherical shape by the host planet's gravity to create moons. HIW

WHEN WILL WE GO TO THE RED PLANET?

21 The nation most likely to be the first on Mars is the USA. NASA is now testing its Orion spacecraft, which it plans to use to transport humans to and from Mars along with another vehicle. NASA's provisional schedule will first see humans return to the moon in the 2020s, before landing on an asteroid towards the end of that decade and finally putting humans on Mars in the 2030s. HIW



WHERE IS THE OFFICIAL LINE OF SPACE?

The official line at which space starts is the Kármán line, 100 kilometres (62 miles) above sea level. Gases in the atmosphere scatter blue wavelengths of visible light to produce a blue glow above Earth. The higher you go the thinner the atmosphere becomes until the glow disappears. This definition is used by space agencies to determine when something has reached space. Theodore von Kármán (1881-1963) calculated this as the point at which a vehicle would have to be in orbit to maintain its altitude. HIW

HAS OUR SOLAR SYSTEM EVER HAD MORE PLANETS IN IT?

23 Other than Pluto, which was declassified from a regular planet to a dwarf one in 2006, there have never been additional planets in our solar system. However, some scientists believe there is a planet larger than Jupiter lurking at the edge of the solar system. HIW

COULD THE SUN TURN INTO A BLACK HOLE?

Put simply, no; the Sun does not have enough mass to collapse and form a black hole. At the end of its life, which will be in a few billion years, it will expand to form a red giant, consuming the four inner planets of the solar system in the process. HIW



HOW COLD IS SPACE?

Cold, but not as cold as it could be. In the Sixties, two US radio astronomers found an unusual microwave signal. They had accidentally discovered an echo from the Big Bang – light that was emitted when the universe had cooled down to about 3,000°C (5,432°F), cool enough for the first atoms to form. Thanks to the expansion of the universe this light has now been stretched to -271°C (-455°F), just 2.7°C (-37°F) above absolute zero, the lowest temperature possible where all motion (apart from quantum wobbling) ceases. HARRY CLIFF

"...where millions of stars are packed into a clump that is 50 light years across, stellar collisions frequently occur – maybe once every 10,000 years" somak Raychaudhury

COULD WE TRAVEL TO EXTRASOLAR PLANETS?

Yes, it is possible to travel to an exoplanet without breaking the laws of physics. However to do so might mean breaking the bank, because it would be extremely expensive. And it might also mean breaking some laws of biology, because it would take many, many generations of human life – note that nearby stars are typically about ten parsecs, or 30 light years, away from us. So if a spaceship could travel at only one per cent of the speed of light, it would still take 3,000 years to fly there! **WESLEY TRAUB**

Outer core

Surrounding Jupiter's core is metallic hydrogen, where hydrogen gas has been compressed into a metallic electrically conducting liquid.

SECRETS OF THE UNIVERSE

HYPOTHETICALLY, COULD A SPACECRAFT FLY THROUGH JUPITER?

No. Jupiter has a rocky core as large as the Earth and, around that, many thousands of kilometres of ice. Above that is a thick layer of a strange material known as metallic hydrogen. But even before you get there, the tremendous atmospheric pressure even a few hundreds of kilometres into the Jupiter atmosphere would have squashed you to a gooey pulp! MICHAEL KHAN

A rotating, circular space station could create artificial gravity



Jupiter's super-dense atmosphere is mainly hydrogen and helium. i i.... Inner core

An Earth-sized rock sits
at the centre, but it's
still largely a mystery.



WHAT'S THE DIFFERENCE BETWEEN A METEOR, METEOROID AND METEORITE?

A meteoroid is any kind of small body (mostly rocks that can be smaller than a speck of dust or larger than a house) that enters the Earth's atmosphere. As such a rock always enters at very high speeds. It will get very hot and start glowing, or even trail a cloud of incandescent matter called plasma, but this varies between meteoroids; this visible trail (or 'shooting star') is called a meteor. Mostly, in that intense heat, all of the rock burns to ashes and dust. However, if some of it survives and falls to Earth, it becomes a meteorite, a piece of space rock that has fallen to our planet's surface. MICHAEL KHAN

CAN WE CREATE ARTIFICIAL GRAVITY IN SPACE?

Artificial gravity is a favourite of science-fiction writers and filmmakers.

Perhaps the easiest way to give the illusion of gravity would be to rotate your spaceship. This would produce a feeling of being pulled towards the outside of the

ship in the same way you feel pulled sideways whenever you go round a sharp corner quickly in a car. Long-distance space travel would most likely require some form of artificial gravity in order to avoid the negative health effects of weightlessness. HARRY CLIFF

ARE THERE SUCH THINGS AS 'WHITE HOLES'?

A black hole is a phenomenon from which nothing – not even light – can escape. However, some theories point towards the existence of an 'opposite' black hole, into which nothing can enter. Their existence has never been confirmed, and indeed their very nature is a paradox. If nothing can enter a white hole, and everything leaves it, then surely it should not exist. Stephen Hawking argues that black and white holes are one and the same. For now, the possibility of whether they exist remains a mystery. JONNY O'CALLAGHAN

IS IT CERTAIN THAT SOME DAY WE'LL FIND ALIEN LIFE?

It would appear so. The Drake equation is one of several that predicts that the probability of finding life elsewhere is 100 per cent certain. If we consider that life on Earth took just several hundred million years to evolve, and the universe has existed for at least 14 billion years, then it is likely that other planets have had a much longer time to support life than ours. With every star now thought to host at least one planet there are billions of potential homes out there and it's highly unlikely that not one of these supports life like Earth. JONNY D'CALLAGHAN

WHAT'S THE BRIGHTEST THING YOU CAN FIND IN THE UNIVERSE?

Gamma-ray bursts are often said to be the most luminous emitters of electromagnetism in the cosmos. These bursts of energy can last for several minutes and are released when a supermassive star collapses during a supernova. However, quasars (the areas around a black hole) are also among the brightest objects in space. HIW

WHY DOESN'T JUPITER EXPLODE?

34 While Jupiter is mostly made up of hydrogen it contains very little oxygen. Fire needs fuel, heat and oxygen in order to ignite. Jupiter has heat in the form of lightning and the fuel is hydrogen, but with such relatively low levels of oxygen no combustion can occur. **HIW**

DO WORMHOLES EXIST?

35 Wormholes have been theorised by many famous physicists, such as Stephen Hawking, but so far they have never been discovered. They act as a 'fold' in space-time, allowing us to traverse long distances in an instant. However, their existence is the cause of much debate in the astrophysics field. HIW

WHAT ARE ION DRIVES?

36 Ion drives are a particularly efficient means of spacecraft propulsion. Ions – electrically charged atoms – are accelerated at high speed from the engine and thus provide a weak but steady thrust force that propels the spacecraft in a controlled way. HIW

ARE YOU WEIGHTLESS IN ORBIT?

37 The very essence of being in orbit means that you are not weightless. Being in orbit means the gravitational pull of the body you are orbiting is pulling you inwards. This in itself gives you weight, albeit only a small fraction of what you'd experience on the surface of that celestial body. HIW

HOW DID THE VAN ALLEN BELTS FORM?

The Van Allen belts are areas where electrically charged particles from the Sun are trapped in the Earth's magnetic field. As long as the magnetic field holds up, so will these belts. However, the Earth's magnetic field reverses polarity every 450,000 or so years and such a reversal is long overdue. When it happens, the magnetic field will collapse and the radiation that is now held back will reach Earth's atmosphere or even the surface. MICHAEL KHAN

HOW IT WORKS

WHAT DEFINES THE BOUNDARY OF THE SOLAR SYSTEM?

39 If you travelled out of the solar system you would eventually reach a point where the Sun's influence reduces to zero and interstellar space begins. This boundary is not clearly defined, but based on information from NASA's Voyager probes it is thought to be roughly up to 4,000 times farther from the Sun than Pluto. HIW



WHY DO ROCKETS TAKE OFF CLOSE TO THE EQUATOR?

The Earth spins on an axis that runs through both poles. This means the poles experience little to no rotational force from the Earth, whereas the equator experiences the maximum possible force. By launching close to the equator, rockets get an extra boost of speed from the rotation of the Earth that helps them reach orbit. **HIW**

HOW MUCH DOES THE EARTH WEIGH AND WHO WEIGHED IT?

41 If you could put it on a theoretically unbreakable scale, the Earth would weigh in at a hefty 6 trillion trillion kilograms (13.2 trillion trillion pounds). It's weighed by adding up the sum of its parts and accounting for its gravitational pull. The Earth is also constantly gaining weight from incoming dust and meteorites – about 45,000 kilograms (99,208 pounds) a year. HIW

WHICH PLANET HAS THE LARGEST MOON?

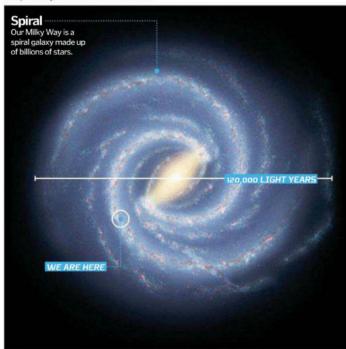
42 Jupiter has the largest moon in our solar system. It is called Ganymede and it is roughly three times the size of our own moon. HIW

IS THERE ANY SOUND AT ALL IN SPACE?

43 Audible sound for humans is essentially the vibration of air particles, and as there aren't any of these in the cosmos then there isn't any sound. However, there is 'sound' in the form of different types of electromagnetic radiation, such as light and radio waves, which we can interpret. HIW

HOW BIG IS OUR GALAXY?

Our galaxy, the Milky Way, is made up of stars and a substantial amount of gas and dust, which can be imaged by optical and radio telescopes. These are spread through a flat disc that's about 120,000 light years across. Our solar system is approximately 25,000 light years away from the centre of this galaxy, orbiting in a circular path around it. However, our galaxy is embedded in a large spherical ball of dark matter, whose mass is at least ten times that of the stars in the galaxy. We cannot see dark matter, but we can feel its gravitational pull. We know that this dark matter 'halo' is at least 500,000 light years across, though we don't yet know how large it is precisely. **SDMAK RAYCHAUDHURY**



WHAT WAS THE SPACE RACE?

The space race started in 1957 when the Soviets launched their first Earth satellite, Sputnik 1. Both Soviets and Americans understood the importance of space; this was the high frontier – whoever dominated space would dominate the Earth. Therefore, both superpowers attempted to be the first to conquer the challenge of space exploration. Initially, the Soviets had some successes, but finally, the USA scored the decisive victory by landing humans on the moon, only 12 years after Sputnik 1. Very rarely has such a massive jump in technology been achieved in peacetime, and rarer still has a scientific venture captured the hearts and minds of the world's youth to this extent. [The world watched the first moon landing on TV], fervently wishing the two brave men who had set out on this epic journey onto the surface of the moon would return safely. Everybody who lived through these years felt he or she was witnessing the most important moment in human history. It is perhaps ironic that the 'space race', which had started out as a quasi-military endeavour, turned out to be something that united all of humanity, if only for a short time. **MICHAEL KHAN**

WHAT'S THE FUTURE OF SPACECRAFT?

The first thing we need is a larger rocket than those available now. Several companies are working on those, mostly in the USA. With such a rocket, we can place large elements, eg of a hotel, a lab, but also modules of an interplanetary spaceship in Low Earth Orbit (LEO). The next step would be more efficient propulsion systems. Ion propulsion is a first step but it offers very low thrust and also requires a lot of electrical power in order to operate. Probably, there will be nuclear propulsion units that offer high thrust, high efficiency and still are not too large to be used on a spaceship, MICHAEL KHAN



COULD SPACE TRAVEL FOR THE COMMON MAN EVER BE A REALITY IN OUR LIFETIME?

Very likely. With the advent of commercial companies investing in space travel, space tourism and space stations, transport capacities will increase, infrastructure will be set up and prices will drop. Although spaceflight will likely be a pastime of the well-heeled for some time to come, at some not-too-far point in the future taking a spaceship to the moon will be as commonplace as taking a jet plane is to us today.

MICHAEL KHAN

SPACE RACE TIMELINE



4 October 1957

Sputnik 1 is launched by the USSR, the first manmade satellite to enter Earth orbit.



1959 NASA's Explorer 6 returns the first image of Earth from space.



12 April

1961 Yuri Gagarin becomes the first human to enter space and orbit the Earth on Vostok 1.



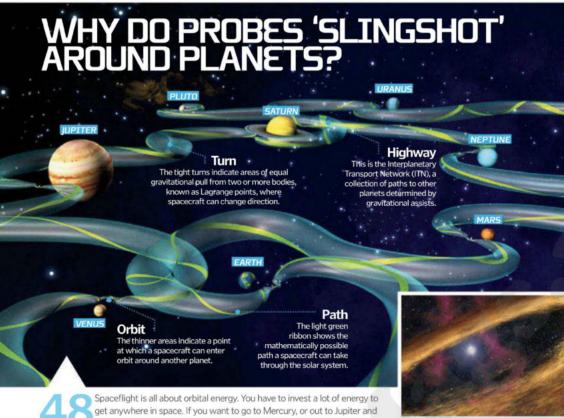
The USA launches the first active communications satellite, Telstar 1.



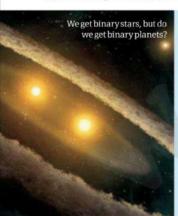
18 March 1965 Alexey Leonov

Alexey Leonov becomes the first human in open space on Voskhod 2.

SECRETS OF THE UNIVERSE



beyond, then the energy needed for that is so great that even the largest rockets couldn't launch a decent-sized spacecraft capable of the trip. So what is done is passing close to large planets, such as Venus and Earth, as the planet's gravity will change the spacecraft's direction. If you compare the spaceship's velocity with respect to the Sun before and after the encounter, you can see a distinct shift - which is the same as a change in orbital energy. It's like a tennis ball being hit by a racket, although the spacecraft of course does not actually hit the planet! Such 'slingshot' or 'swingby manoeuvres have opened up the solar system to humanity. We would not be able to explore Mercury or the outer planets without this technique. MICHAEL KHAN



BINARY PLANETS?

Binary planets are certainly possible, but none have yet been found. But if we stretch the meaning of 'binary' to include a really small body around a large one, then the Earth-moon system is a binary planet. If we stretch the meaning in another way, to include very small bodies, then there are examples of asteroids that orbit each other, and the pair orbits the Sun, so these would qualify too. It is quite possible that NASA's Kepler telescope will eventually find a binary planet, and that will certainly make the news! WESLEY TRAUB

HOW DO PULSARS FORM?

Pulsars are rotating neutron stars with a very high magnetic field, which creates a beam of light that sweeps around like a lighthouse. Neutron stars are created in the violent death of massive stars (ie stars more than eight times more massive than the Sun). When such a star has exhausted its fuel at the end of its life, it can no longer support its own weight and, as a result, collapses in a spectacular explosion called a supernova. The core of the old star gets violently compressed to the densest form of matter that can exist in nature - a ball of matter consisting exclusively of neutrons. How the newly formed neutron star gets the strong magnetic field that pulsars show is not yet understood. KLAAS WIERSEMA

HOW DO ROCKETS MOVE THROUGH SPACE IF THERE'S NOTHING TO **PUSH AGAINST?**

Under Newton's Third Law, every action has an equal and opposite reaction. So, even though there's nothing to push against, the force of the propellant leaving the rocket pushes it forwards with the same amount of power. HIW

WHICH COUNTRY SPENDS THE MOST MONEY ON SPACE EXPLORATION?

As you'd expect, the USA is leading the way, and by some margin, but other countries like China are beginning to catch up. NASA's budget for 2011 was \$19 (£12) billion. HIW

IS THE SUN BRIGHTER ON THE INSIDE?

According to Stefan's Law, brightness per square foot is proportional to the fourth power of the temperature. As the temperature at the core of the Sun is many thousands times greater than it is on the surface, by this logic it must indeed be trillions of times brighter on the inside. HIW

WHAT'S THE FURTHEST POINT IN SPACE THAT WE CAN SEE THROUGH A TELESCOPE?

The furthest that we can see from our planet is as far as the limit of the observable universe. This is approximately 14 billion light years away from Earth, where light from the outer reaches of the universe is only now just reaching us. HIW

WHAT IS AT THE EDGE OF THE UNIVERSE, IF THERE IS ONE?

As discussed in the previous question, there is an observable limit to how far we can see (about 14 billion light years away). At the 'edge' of the universe we can see remnants of the Big Bang in the form of X-ray radiation, but what lies beyond this edge we do not know - at least not yet. HIW

WHERE DOES THE MATERIAL THAT GOES IN A BLACK HOLE END UP?

Most of the matter that enters a black hole ends up in a singularity, which is an infinitely dense point no bigger than the full stop at the end of this sentence. However, some black holes reach a theoretical mass limit and, when they do, they fire out excess matter in jets of radiation known as Hawking radiation. IONNY O'CALLAGHAN

ARE THERE ANY

1 March 1966

The USSR 'lands' the first probe on another planet - Venera 3 on Venus - but it crashes.



Frank Borman, James Lovell and William Anders are the first men to orbit the moon.

WWW.HOWITWORKSDAILY.COM

20 July 1969 Aldrin become the first



men to walk on the moon.

19 April

1971 The USSR launches the first space station into Earth orbit. Salvut 1.



The USA and USSR collaborate for the first time, docking Apollo and Sovuz in orbit.

HOW IT WORKS

COULD WE MINE THE MOON FOR MINERALS?

57 We could mine minerals from the moon, but we wouldn't have much use for them. The moon is rich in helium-3, which could be a very useful source of energy, but we currently don't possess the technologies to use it. HIW

HOW MUCH DOES IT COST TO SEND SOMEONE INTO SPACE?

Like aeroplanes on Earth, that depends on whom you fly with. A flight on Virgin Galactic will cost you \$200,000 (£125,000) when it launches in the coming years, while a flight on board Russia's Soyuz spacecraft could cost a few million dollars. HIW

HOW LONG DOES IT TAKE FOR A MESSAGE TO TRAVEL FROM MARS BACK TO EARTH?

Signals sent to spacecraft in orbit and beyond are limited by the speed of light. Sending and receiving a signal from one of the spacecraft around, or on the surface of, Mars takes up to 45 minutes, depending on how far the Red Planet is from Earth in its orbit. **HIW**



COULD THE ISS BE USED TO LAUNCH OTHER SPACECRAFT?

No, it's not designed to do so and has no facilities that would support such a function, such as a large propellant reservoir or a launch pad, etc. The ISS would have to be a lot bigger and manned by more people to serve as an orbital launch base. MICHAEL KHAN

WHAT IS THE UNIVERSE SHAPED LIKE?

61 No one knows for sure, but there are three main schools of thought. Some think the universe is flat, some think it is more of a cylinder shape and others think it is a sphere. **HIW**

WHAT'S THE MOST COMMON ELEMENT IN THE UNIVERSE?

Hydrogen is by far the most abundant. It is found in almost every object in the cosmos, and is also the main component of stars. Helium is the second most common, followed by oxygen and carbon. HIW



HOW DO WE CALCULATE THE AGE OF OUR SOLAR SYSTEM?

The most widely used technique to find out something's age is radiometric dating. The materials we want to date contain very small amounts of naturally occurring radioactive elements. These elements change into other non-radioactive elements in a process called radioactive decay. We know precisely how long it takes for a given radioactive element to decay. so by measuring the amount of these elements in a rock, we can work out the age. To establish how old the solar system is, we use this technique on meteorites. These were formed at the same time as the Earth but, unlike rocks on our planet, have not been through weathering, volcanic processes and such, and therefore provide us with a clean view of the oldest parts of the solar system. KLAAS WIERSEMA

WOULD IT BE DANGEROUS TO TRAVEL AT LIGHT SPEED?

No, but getting there might prove hazardous. Galileo taught us that all uniform motion is relative – in other words it's impossible to tell the difference between travelling at constant speed in a straight line and being stationary. Imagine you're flying away from Earth on a spaceship just slower than the speed of light. Without looking out the window there would be absolutely no way of telling you were moving at all. So it really would be quite safe. On the other hand, accelerating up to the speed of light could be a lot more risky. **HARRY CLIFF**



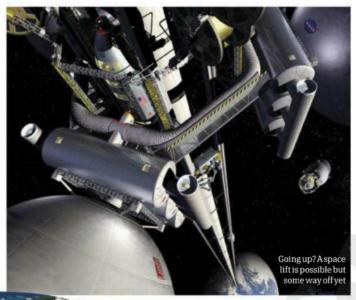
WHO NAMES NEW PLANETS?

There is currently no official naming system in place for planets found outside our solar system other than their scientific classification, which contains information on the star the planet orbits and its order away from the star in relation to other planets. Due to their often lengthy and complex monikers many planets are also christened with unofficial nicknames, although these can vary. For example the oldest planet yet discovered – PSR B1620-26 b – is known unofficially as both Methuselah and the Genesis planet. JONNY O'CALLAGHAN

SECRETS OF THE UNIVERSE

WHY CAN'T WE BUILD A SPACE ELEVATOR YET?

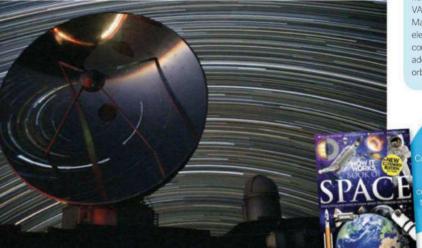
We're not too far off. A space elevator would need a cable material that is far stronger and lighter than all materials available to engineers today. A new material called carbon nanotubes might do the job, but we don't have the technology yet to manufacture cables of this material that are longer than a few centimetres. Also, we currently wouldn't be able to launch the large machinery and the amount of raw materials into geostationary orbit (36,000 kilometres/22,369 miles up) that would be required to build the elevator. Space elevators, unlike buildings on Earth, would need to be built starting at the top and working our way down to the foundations. MICHAEL KHAN





WHERE'S THE BEST PLACE FOR TELESCOPES ON EARTH?

Telescopes that use ordinary (optical) light have to be situated in high and dry places, where the air is clearer. This is why optical telescopes are found on the tops of high mountain ranges in or near deserts, eg in the Andes in northern Chile, the high mountain tops of Hawaii or in eastern Australia. Radio telescopes can see through clouds, but are vulnerable to industrial activity. The biggest radio observatories are in New Mexico in the USA and north of Pune in India. X-ray, gammaray, ultraviolet and infrared radiation cannot penetrate the atmosphere, so telescopes for this kind of light are placed in orbit around the Earth. SDMAK RAYCHAUDHURY



WHAT ARE THE BEST TYPES OF SPACECRAFT PROPULSION AROUND?

The furthest spacecraft from Earth, NASA's Voyager 1, has used radioisotope thermoelectric generators to go about 18 billion kilometres (11 billion miles) in 34 years. Solar sail spacecraft, which use a large and light sail to ride on the solar wind, have a weak rate of acceleration and ion drives are reliable but too weak for deep-space missions. NASA's solar-powered Juno probe, en route to Jupiter, is the furthest spacecraft powered by the Sun alone, but has limited power. The best bets for long-distance propulsion are either nuclear power or the in-development VASIMR (Variable Specific Impulse Magnetoplasma Rocket), which uses electromagnetic thrusters for continued propulsion and may be added to the ISS to keep it in a stable orbit. JONNY O'CALLAGHAN

WINNING TWEET!

ongratulations to reader James (a)

Cocoa_Pig) for submitting the
winning question in our Twitter
ompetition: "How do rockets move
through space if there's nothing to
push against?" He wins a

How It Works Book Of Space
Extended Edition

HOW OFTEN DO METEORITES HIT OUR PLANET?

Thousands of meteoroids enter Earth's atmosphere every year, and hundreds of these hit the surface of our planet. However, the ones that reach the surface are very small after mostly burning up in the atmosphere. **HIW**

WHAT'S THE BIGGEST KNOWN ASTEROID?

71 Vesta is the largest asteroid. It has a diameter of about 530 kilometres (330 miles) – roughly 1/25th that of Earth's. It is located in the asteroid belt between Mars and Jupiter. **HIW**

IS THERE A CENTRE OF THE UNIVERSE?

No, there's no centre. Since the Big Bang, the universe has been expanding; however, everything is expanding away from everything else at an almost equal rate. **HIW**

WILL THE MILKY WAY AND ANDROMEDA HIT?

73 Yes, they probably will. Our neighbouring galaxy Andromeda, which is about 2.5 light years away, appears to be on a collision course with the Milky Way. They are expected to collide in 5 billion or so years. **HIW**

IS OUR SUN ONE OF A PAIR?

While another has never been found, some astronomers think our Sun is part of a binary star system, with the second star located far outside the solar system. All evidence points to 'no' at the moment though. **HIW**



WHAT IS DARK MATTER?

Most astrophysicists think dark matter must exist as galaxies appear to be spinning too fast for the gravity created by all the stuff we can see to hold them together. The most widely accepted explanation is that galaxies contain invisible matter that doesn't emit or reflect light, hence 'dark'. HARRY CLIFF

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HNOLOGY





















This month in **Technology**

If you think mobile phones are smart now, then you're in for a revelation this issue as we see how they're getting faster and brainier all the time. Other clever machines featured are meters that measure your electricity usage, ECG heart-rate monitors and the biggest drill on Earth that's used to bore tunnels through mountains.



28 World's largest drill



30 Ouartz clocks



31 Flare guns

TECHNOLOGY

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- 30 Ouartz clocks
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- 31 Flare guns
- 32 Andy Pad Pro





Upgraded hardware, software and networks will come together to offer an amazing smartphone experience



Do you remember a time when you got by with a smartphone packing a tiny amount of memory, a

low-resolution screen and a form that was so large it could have been used to anchor a small boat? We laugh about those times now, but in the near future we will be sniggering in exactly the same way about our current phones. Wouldn't it be nice to know what's

going to power the smartphones of tomorrow and how future developments will make the smartphones of today look positively archaic? Well, let's find out.

Mobile networks will be 'much' faster. 4G will replace the 3G networks we use now and offer ten times the speeds available today. Future smartphones will have to cope with the power such speeds require and so

battery technology will also have to step up. Fortunately, a battery has already been developed that can last for a whole week and, believe it or not, recharge in only 15 minutes. It has been built by addressing two limitations of current battery technology. First, lithium atoms are required to hold a battery charge between an anode and cathode - the two ends of the battery - and they are typically built in layers of one lithium

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1. iPhone 4S 3.9-centimetre (3.5 nch) screen, but the etina-busting resolution still makes images and



2. Nokia Lumia 800 The Lumia screen, at 9.4 metres (3.7 inches), orks perfectly with the Windows Phone software to reate a lasting impression



3. Galaxy Nexus (4.65-inch) display on the Galaxy Nexus is perfect for entertainment and general organisation. It makes every

DIDYOUKNOW? A new mobile phone is in development that is made from bamboo, which is both durable and incredibly light

NOKIA 0

INSIDE NETWORK DEVELOPME

The rush to offer complete high-speed coverage continues relentlessly and network providers are using a variety of technologies to give the mobile user all of the speed they desire, whenever they need it. More Wi-Fi hotspots will pop up in businesses and town centres, using the exact same technology as a home router does. They are connected to the fixed telephone network, like your home broadband, and then the bandwidth is available wirelessly via the hotspot. Mobile network operators are increasingly offering bundled Wi-Fi services to help them cope with mobile data demand, plus city-wide schemes to offer free Wi-Fi for all, such as Wi-Fi London which is aiming to have

near-complete Wi-Fi access in time for the 2012 Olympic Games.

4G will offer the most obvious benefits to smartphone users and is destined to let us all connect to the mobile internet at speeds upwards of 100 megabits per second. This will be achieved by increasing the amount of spectrum available to mobile operators - more spectrum at 800MHz and 2.6GHz, which represents the equivalent of threequarters of the spectrum available today and took two decades to create. With spectrum secured, operators can then start to build the required infrastructure to enable users to take full advantage of the greater speeds through a host of devices from smartphones, dongles,

laptops and possibly even desktop computers. With fewer networks competing for these spectrum bands thanks to network-sharing deals, the process should complete quite quickly. Orange and T-Mobile already utilise each other's networks, via the Everything Everywhere brand, and Vodafone and O2 have been working on jointly building new sites that they can both serve to customers. This is on top of the long-term network-sharing arrangement between 3 and T-Mobile.

Potentially, mobile data will be advanced enough to pose a serious threat to home broadband connections and could eventually signal the end of the land line for many people.



atom to six carbon atoms, but by sandwiching clusters of silicon atoms between the layers and by not using carbon atoms, the number of lithium atoms can be greatly more power can be held. Tiny holes shortcut to the anode which makes quicker than the batteries we use now; just imagine being able to charge your phone for 15 minutes

Display technology will also evolve significantly and, because it is the most used part of any smartphone, we can count on greater resolutions, clarity and bright light performance. However, we can also expect them to become flexible. Displays of today are built by attaching organic LEDs to glass, but in the future we can expect LEDs to be 'printed' onto pliable plastic instead which will make

them completely flexible. Imagine can roll up and stuff in your pocket, a device that can be used as a phone during the day and then a tablet when you require a bigger screen at night. It sounds impossible because of all the components that need to sit behind the screen, but take yourself back to the future battery technology - if they can hold ten times the charge of today's batteries, they can also be made ten times smaller and thus never impede on the display's flexibility.

This ongoing process of miniaturisation will also be true for all other smartphone components, such as processors and cameras, and will complete the ultra-portable setup for future phones.

"This process of miniaturisation will be true for all other smartphone components, such as processors and cameras" As the smartphone becomes the compact camera of choice for most, so the camera technology will improve beyond what we can conceive today. Light-field cameras will no doubt be snuck into the latest high-end phones and these will give you the ability to take a shot and focus it when you get home. Such devices are able to do this as microlenses are placed within the focal plane of the camera lens just behind the main image sensor and these allow the parts of a photo that are not in focus to be analysed later and then matched to the corresponding image parts that are in focus. From this data, a perfectly focused photo can be created irrespective of how bad a photographer you are



The Huawei Ascend P1S is currently the world's thinnest phone at 6.68mm (o.26in).

Snap happy

The camera of the Ascend P1S packs 8MP, an autofocus setting and a dual-LED flash.



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WORKS TECHNOLOGY

"Behind all of the parts you see and touch will sit some hefty processing power"

Cutting-edge smartphones



and this will likely become as important to future smartphone camer technology as lenses, megapixels and everything else put together. You will never take a bad snap again!

Behind all of the parts you see and touch will sit some hefty processing power that will make even the fastest of today's home computers look feeble. Quad-core processors, which spread the load of intensive tasks evenly over each core to reduce power requirements, are already available in mobile form, but the expectation of 16-core processors and above is not unrealistic. With so many powerful cores you will be able to run everything you can on today's smartphones, but many times over. The

technology will allow the most resourcehungry tasks to use as many cores as they need and still undertake completely separate operations, thus offering an experience which never slows down. This ties in nicely with the faster network speeds and will offer a super-smooth end-to-end experience that is completely unlike a computer.

Imagine, you will be able to roll up your phone or unfold it into a tablet when you want to. You will charge it only once a week for a few minutes. You will never take a bad photo or even consider hardware and mobile network speeds. Now look at what you use today. There's no doubt that we will all look back to today and wonder at how we survived.

INSIDE A FEATURE-PACKED PHONE





Apps

Each of the most popular mobile operating systems now boasts many thousands of apps that can be used for everything from internet banking through to satellite navigation.

Power

2 The processing power of highend mobiles is comparable to the internals found on many laptops and netbooks from a couple of years ago and their power is set only to grow.

Voice recognition

3 Voice-recognition apps, like Siri, are fast becoming a preferred method for data input and are expected to challenge touchscreen keyboards in popularity in the future.

Photography

Smartphone cameras now rival compact cameras from two or three years ago in terms of megapixels and they are improving quickly in optic and zooming capabilities too.

Storage

5 The amount of memory on modern mobile phones lets the user carry thousands of photos, thousands of songs and as much data as they could possibly need when out and about.

DIDYOUKNOW? Future phones are expected to be built to last with unbreakable screens and full waterproofing

TOP FEATURES OF THE LATEST MOBILES



iPHONE 45

Pixel packed
As well as introducing
us tovoice-recognition
feature Siri, the iPhone
4S also boasts the
highest-res phone
screen ever (the Retina
display) and wireless
storage with iCloud.



DROID RAZR

Super materials

The Motorola Droid RAZR features 'a force shield of water-repellent nanoparticles' to protect it from splashes, while the screen is reinforced by Gorilla Glass and Kevlar fibre.



XPERIA S

Hi-def

This phone from Sony Ericsson, which comes to the UK in March, will be the first to include a high-definition 12-megapixel camera, using a CMOS sensor for perfect pictures.



ALAXI NEX

Powerful

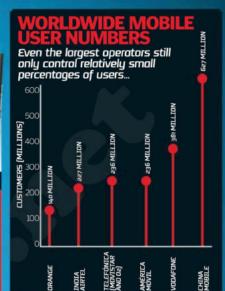
The first to run the Android 4.0 lce Cream Sandwich OS, Samsung's Galaxy Nexus packs a speedy 1.2GHz dual-core processor and a Super AMOLED screen.



LUMIA 800

Xbox connected

Nokia's Lumia 800 is regarded as the greatest Windows phone available. The ability to link it to your Xbox 360 is also extremely attractive for gaming fans.



OTOROLA 11:35 veri<u>zon</u> d

THE TRUTH ABOUT SIGNAL STRENGTH

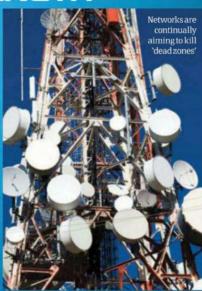
Signal strength is measured in decibels (dB). The transmissions between mobile device and base station are of a relatively low power, so the figures you see are usually microvolts per metre; simply put, the greater the number of microvolts, the stronger the signal.

phone do not accurately represent the true signal. The bars do not account equally for decibel loss – for instance, having two out of four bars does not mean that you are receiving at half power, as the smallest three bars together cover less power loss than the top single bar on its own. As you can see, this makes the system highly inaccurate and you could be classed as having a 'low-strength' signal even with three bars showing.

battling to improve coverage and they still use the same solutions they always have: more base stations, higher power transmissions, taller antenna masts and stronger antennas, and, more recently, femtocells to provide signal in high-traffic but low-coverage areas. As with all radio services, the higher the power, the further the signal will be transmitted - equally, the lower the frequency of the spectrum, the lower the power needed to achieve the same distance. A mobile operator with spectrum at 800MHz will need to broadcast at a lower signal strength than an operator with spectrum at 2.6GHz to achieve the same coverage, assuming an equivalent number and placement of base stations.

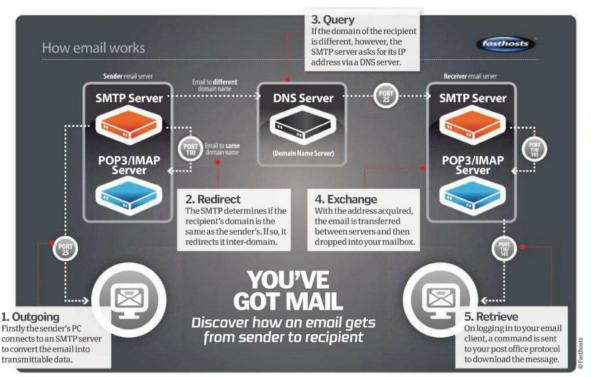
Network providers use coverage noticers to spot 'dead zones' – areas with no coverage – and these devices will emit a beep when

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within one. They can be used alongside tracking software in cars or on foot to build a map of general coverage over wide areas. Population density and dead zone data is used with destructive interference information to create a picture of where coverage is required most urgently. Destructive interference can be caused by large buildings constructed from metal, which can kill off a signal indoors, trees, terrain and many other obstacles. This makes the science behind coverage extremely complex but something networks continually use to improve signal strength for us all.

"The SMTP converts the information to a TXT file to send across the web"



How do you send and receive emails?

How It Works explains how an email can cross multiple networks and entire continents in just a few seconds



An email is an electronic text message constructed and sent through an email client (such as Microsoft Outlook). Once written, the sending process begins, with the email client connecting to a simple mail

transfer protocol (SMTP) server via the internet and through a DSL or line modem. The client then communicates with the SMTP part of your designated email server (for instance, GoogleMail) through a dedicated port.

During the transmission between your email client and server, your email client relays the header information of your email – in particular the recipient's address and the contents within the email body. At this point the SMTP converts the information to a TXT file to send across the web.

Based on the header information within your email, the SMTP server then contacts the recipient's correct email server. Using the '@' sign as a divider, the SMTP takes the second part of the address to determine the location of the recipient's server. If the domain name is the same as the sender's, the SMTP simply transfers the email information across. If the domain name is different, the SMTP contacts a DNS (domain name system) server and requests the exact IP address for the relating domain name's hosted email server, such as those provided by Fasthosts.

Once the IP address has been obtained, the sender's SMTP server sends out a signal message to the recipient's SMTP over the web and all its gateways informing them that they have

received a message. From then, the two servers converse with each other and the email is transferred.

The TXT file converts back into its original form, dropping the message into the bottom of the addressee's mailbox. Finally, when the recipient logs in to their email client, it connects to the internet and commands the recipient's POP3/IMAP (post office protocol/internet message access protocol) server to download all pending messages for viewing on the local machine.





JARGON BUSTER

Break through the complex lingo with our handy guide

Email client:

An application used to view, compose and send emails. Examples include Microsoft Outlook, Microsoft Exchange or web-based ones such as www.mail.com.

Email server:

A remote machine hosting your email, perhaps sourced from a freemail provider or a web-hosting company such as Fasthosts. The server is split into an SMTP server and a POP3/IMAP server.

Email address:

Your unique online site for emailed material that uses a domain name, either individual to you or shared by a company/institution, etc.

DNS (domain name system): A remote server used to convert domain names to IP addresses (unique 32-bit numbers).

SMTP (simple mail transfer protocol):

The part of the email server that starts the process for outgoing mail and receiving mail into the correct server.

POP3 (post office protocol)/IMAP (internet message access

protocol): These parts of an email server store and download incoming mail for each user account.

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"The largest of these cutterheads is a 15.2-metre (49.8-foot)-across Herrenknecht-brand EPB Shield"

World's largest drill

Our inability to make inroads into some of Earth's most impenetrable terrain was a problem once... then they built tunnel-boring machines!

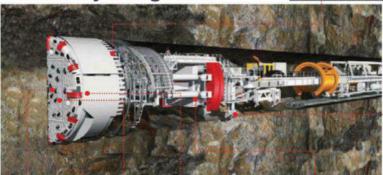


Tunnel-boring machines are designed to drill large-scale excavation holes into terrain that would otherwise be difficult or even impossible to penetrate. They are commonly used in the

construction of underground tunnels and by passes – modern motorway and train tunnels are often built with them – and they are specially designed not just to cut through rock and earth, but crucially to support the tunnel in the process. Additionally, today's most advanced boring machines are engineered to remove debris as it is generated by the drilling process, with rocks and rubble transported to the rear of an assembly on conveyor belts for easy disposal.

Key to any tunnel-boring machine though is its colossal cutterhead, a cylindrical wall of disc cutters and drills that – in partnership with extreme pressure, which is generated by the bore's thrust cylinders – literally crush any material that sits in its path. The largest of these cutterheads currently in operation is a 15.2-metre (49.8-foot)-across Herrenknecht-brand EPB Shield, a record-breaking piece of machinery that was used to carve out chunks of earth in the construction of Madrid's M-30 motorway north tunnel. As you can see on this page, the total assembly is huge and it weighs hundreds of tons.

The anatomy of mega-drills



Cutterhead

All the excavation tools are mounted in the cutterhead, which also supports the tunnel face.

Disc cutters

These are mounted in the cutterhead and roll in concentric circles over the tunnel face. The contact pressure crushes the rock.

Buckets

The system's buckets transport the excavated rubble behind the cutterhead onto a conveyor belt system.



Roof bolting unit

This part can rotate around the machine's axis and drills holes into the rock for supporting metal bolts.

Walking device The rear of the bore and the back-up systems rest on the feet of the walking device. They are lifted as tunnelling progresses and the back-up system follows.

Thrust cylinders
These press the rotating
culterhead against the

HOW IT WORKS
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DID YOU KNOW? A tunnel-boring machine excavated 10.5 million cubic metres of rubble to carve the Gotthard Base Tunnel



"An ECG machine detects and amplifies the changes in electrical impulses on your skin as your heart contracts"

Crystal timepieces / Baby monitors / ECGs

How do quartz watches work?

Keep accurate time with nothing more than a lump of rock

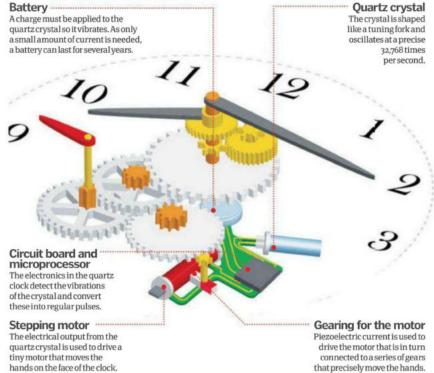


The quartz watch uses a special quality of the crystal (actually

made of a silicon dioxide compound) that was discovered to vibrate at a very regular 32,768 times per second. Clocks and watches that utilise quartz are generally very accurate but they do lose and gain time; this is because the crystal reacts to changes in the atmosphere such as shifts in temperature and pressure.

Quartz watches work because the crystal itself is piezoelectric, which means it vibrates when you apply an electrical current to it. The circuit that the quartz crystal sits at the heart of also collects the energy that the piezoelectric effect generates to drive the motor that moves the hands or, alternatively, power the LCD display if it's a digital display.





Wireless baby monitors

How to hear and watch your baby on your phone or tablet PC with the latest surveillance technology





In their most basic form, baby monitors are just a radio transmitter that uses a fixed frequency usually in the 49.300MHz, 900MHz or 2.4GHz ranges. To reduce interference, some systems also employ

 $\label{lem:digital} digital enhanced cordless telecommunications (DECT) \\ technology, similar to that used in cordless phones, while others \\ can be linked to smartphones or tablet computers.$

 $A\,modern\,monitor\,works\,by\,detecting\,any\,sound-or\\movement\,if\,a\,video\,camera\,is\,also\,being\,used-and\\transmitting\,the\,audio\,or\,video\,wirelessly\,to\,a\,receiver.$

The devices work in a similar way to two-way radios with the addition of a sensor attached to the microphone that triggers the transmission of the audio or video. Baby monitors are usually what is called 'half-duplex'; this allows one monitor to transmit its signal to any number of receivers simultaneously.

Digital baby monitors have mostly replaced their analogue counterparts. Using an iPad or smartphone now means baby surveillance can be done anywhere, eg systems like WiFi Baby utilise the 3G network for super-clear pictures and sound.

How do ECGs measure your heart rate?

To diagnose a range of illnesses, accurately monitoring your heart rate is essential



Measuring your heart rate is now easier than ever before. Apps can even use a smartphone's camera to

measure tiny changes in your finger to study your heart, while sports watches with and without chest straps also do the job. But it's electrocardiography (ECG) that is mostly used in the medical world.

An ECG detects and amplifies the changes in electrical impulses on your skin as your heart contracts. The ECG can record the changes in your heart as each heart cell muscle has a negative charge across its outer wall. When the organ contracts the charge alters; this is called depolarisation. The ECG's electrodes pick up these changes as variations in voltage. Heart conditions alter the conductivity of your heart's tissue in specific ways that the ECG can distinguish. An ECG can have up to 12 electrodes to view your heart from many angles to ensure an accurate result.

The digital or paper tracing that the ECG produces includes waves and peaks that can show if there is any irregular activity that indicates any medical issues.





Behavioural change

Once you have a meter installed you quickly become sensitive to the amount of electricity you are using. Energy paranoia can reduce energy usage, which in turn can cut carbon emissions.

Business matters

2 After installing smart meters the World Museum in Liverpool saved huge levels of CO, and £36,000 per year, giving a payback on the initial stake in just over seven months.

Every home will have one

3 It's thought that every home in smart meter by 2020. This is estimated will save consumers between £2.5-3.6 billion over the next two decades.

Go mobile

⚠ In a bid to educate everyone about energy usage, many of the main suppliers now have iPhone and iPad apps that allow you to closely monitor your electricity consumption.

Smart homes

5 These meters are only the first step towards a smart home with systems like AlertMe (www. alertme.com) arriving where you'll be able to monitor energy usage no matter where you are

DID YOU KNOW? The military uses many types of flare, sometimes as a countermeasure against heat-seeking missiles

Electricity smart meters explained

Keep an eye on how much power you're using with one of these clever gauges



Electricity meters come in two varieties: the DIY approach or the fixed meter that is installed by your electricity supplier. Using the DIY

approach the meter monitors your electricity usage via a sensor that clips onto the main electricity cable usually located in your meter cupboard. This sensor has a wireless transmitter that sends your electricity usage data to the display unit, which can be positioned anywhere in your home.

Meters directly connected to your electricity

DIY variety, but they are wired directly into your power supply. Most meters use radio frequency (RF) transmitters in the 900MHz ISM (industrial, scientific and medical) band that is reserved for special radio transmissions as well as systems like Bluetooth, though some utilise the 2.4GHz and 5.8GHz bands. The RF enables your reading to be sent to the supplier.

Smart meters send your readings to your electricity company in about 45 seconds, once a day. Some meters can also be read with portable handheld devices, but you no longer

information to the meter's electronics.



How do flare guns work?

Discover the mechanism that makes this lifesaving device go off

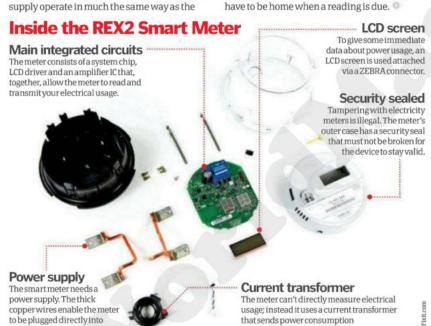


A flare gun works in the same way as any traditional firearm with one key difference: it must ignite its projectile and propel it high into the sky. Generally credited to Edward Very

(1847-1910), the first gun that could fire a flare was tested by the American Navy back in 1882.

When the trigger of a flare gun is pulled, a chain of events begins. First, the flare's propellant is ignited as the gun's hammer strikes the detonator cap. The signal is then pushed out of the gun's barrel through deflagration, which is a subsonic combustion process where an intense burning of gases in a small space generates great pressure.

The short time it takes to ignite the propellant is enough for the flare to also be lit. These objects burn so brightly because they contain magnesium, an element also used in fireworks. Other chemical additives can produce varying colours. In some cases, the flare will also have an inbuilt parachute (most commonly for military use) that prolongs its fall to Earth and extends the average 40-second period that a flare will typically burn for.



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 - Optional accessories: Reverse Engineering CNC Scani 4th Axis, Digitizing Probe



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"The device has a seven-inch capacitive LCD screen with a resolution of 1,024 x 600"



The statistics...



Resolution: 1.024 x 600

Weight: 374g (13.2oz)

Processor: Cortex A8 1GHz

Connectivity: Wi-Fi/Bluetooth

mini-HDMI, headphone jack

The front and rear-facing cameras-0.3 and 2MP, respectively-allowyou to take quick snaps in addition to



The Andy Pad Pro is a low-cost Android-powered tablet relatively new to the market. The Andy Pad Pro's unibody, plastic-composite shell is machined with a high-tension threshold and is purposely designed to withstand drops as well as bumps and scrapes -

something helped by the sturdy body which is 1.27 centimetres (0.5 inches) thick. The operating system of the Andy Pad Pro is a modified version of Android 2.3 Gingerbread that comes pre-installed with a variety of apps. One of its most innovative features is the auto-typing feature - SwiftKey Tablet X - which is a keyboard replacement app that uses an advanced prediction engine (see 'Typing recognition' boxout). Inside is a Cortex A8 1GHz single-core processor with 512MB of RAM and a 3D-capable GPU. For connectivity purposes the Andy Pad Pro has a 3.5-millimetre (0.1-inch) headphone socket, mini-HDMI port, microSD slot and a charging port, while a built-in Wi-Fi receiver supplies access to the web.

The device has a 17.8-centimetre (seven-inch) capa citive LCD screen with a resolution of 1,024 x 600, which can be used for HD movies and games. The screen supports up to five-point multitouch, allowing for a range of gestures and commands to be used with Gingerbread. The tablet also has an accelerometer that can switch the screen between portrait and landscape modes, in addition to providing an alternative method of control in motion-sensitive games.

A stripped-down base unit Andy Pad is also manufactured. At 374 grams (13 ounces) it is 18 grams (o.6 ounces) heavier than the Andy Pad Pro, has only one camera and a resistive (rather than capacitive) 800 x 480 screen. It also has half the memory of the Andy Pad Pro -8GB (again, with the option of upgrading to 32GB with an external SD card) as opposed to the Pro's 16GB.

Typing recognition

How does the Andy Pad tablet learn how you type?

One of this tablet's most advanced features is its typing system. It uses SwiftKey Tablet X, which is a keyboard replacement app that uses a smart prediction engine. From users' Facebook, Twitter and Gmail accounts it learns typing patterns and how they generally construct sentences, ultimately helping users to type much more quickly and efficiently. Software like SwiftKey Tablet X is able to log your writing style in order to more easily predict the words you may type in the future. Aside from its advanced word prediction engine, SwiftKey is also integrated system-wide throughout the Android OS. This means that, despite the application the user types in - be it a stock email client or social-networking tool like Facebook or Twitter-SwiftKey's system tracks and logs text patterns and sentence construction, allowing it to 'learn' their typing style and, as a direct consequence, speed up the writing process. Eventually, users can type full sentences by just tapping words as they appear based on the software's programs.





1. iPad 2 current market leader, pple's powerful iPad 2 remains the king when it comes to



2. Xoom 2 Motorola's second attempt at a tablet computer is considerably better than the disappointing first-generation Xoom



3. Galaxy Tab 10.1

eatest rival, the 25.6-centimetre (10.1-inch) screen of the Galaxy Tab from Samsung makes for an enjoyable tablet experience with a variety of cutting-edge features.

DIDYOUKNOW? Elisha Gray patented the telautograph in 1888, an electrical tablet designed to record handwriting



PRE-INSTALLED APPS ON THE ANDY PAD PRO

Evernote



Evernote write memos

and categorise them with tags, in addition to other devices including your phone and computer. No tablet user should be without this super-handy app.

Dropbox



Ifyou transfer files between

devices then you'll definitely want to use Dropbox. You can store files, images and more in 'the cloud' and access them from any device, anywhere, at any time.

Movies



Movies by Flixster together film

trailers and reviews into one simple application. You can also check out your local cinema listings and see what's new to buy on both DVD and Blu-ray.

Tuneln Radio



This app lets you listen to thousands ofonline

radio stations and over a million on-demand programmes, so you've always got quality audio content to entertain you when you're on the move.



explained

Biology
Chemistry
Physics
General











The science of freezing



This month in Science







SCIENCE

- 38 Washing detergent
- 38 Skin colour

- 42 Gastric bands

Enter the heart-stopping, physics-defying world of the ultra-cold





Put simply, cryogenics is the science of the extremely cold. This is not about deepfreezing your deceased

chihuahua. The freezing of dead people or animals in the hope of future reanimation is called cryonics - not cryogenics - and is less a science than a really expensive alternative to burial. True cryogenics is a field of physics that studies the unique properties and applications of extremely cold liquids, materials and environments.

How cold, exactly, is cryogenics cold? Anything below-150 degrees Celsius (-238 degrees Fahrenheit or 123 Kelvin) and approaching absolute zero (-273 degrees Celsius/-460 degrees Fahrenheit), the coldest theoretical state of matter. To put

those temperatures into perspective, the coldest recorded temperature on Earth - at a research station in Antarctica - was -89.2 degrees Celsius (-129 degrees Fahrenheit or 184 Kelvin). To obtain cryogenic temperatures, researchers must alter the natural states of gases like nitrogen and helium, two of the most abundant elements in the universe. Nitrogen is a gas at room temperature, but if you can bring the temperature of nitrogen past its incredibly low boiling point of -196 degrees Celsius (-321 degrees Fahrenheit or 77 Kelvin), it becomes a supercold liquid that's easy to store and transport in vacuum tanks.

But how do you get anything, especially a gas, to become so cold? Physics, of course! We know that higher pressure means higher energy (heat) and lower pressure means lower energy (cold). To create liquid nitrogen or other liquid gases, regular atmosphericair is compressed in stages. With each compression, the air naturally gets hotter, so it must be cooled using heat exchangers. Once the air is both tightly compressed and cold, it is sprayed into a large storage tank, dramatically lowering the pressure on the gas, causing its temperature to drop so quickly as to become liquefied. Through a distillation process, liquid air can be separated into its component elements like liquid nitrogen, oxygen, hydrogen and helium.

Armed with these hyper-cold liquids (also known as refrigerants), researchers are able to test and study the properties

Cool and clear

Cryogenic cooling drastically reduces signal-to-noise ratio, which is why NASA cools its microwave receivers to cryogenic temperatures for deep-space communications.

Colder, faster

2 Microprocessors in computers run faster when they're cold. Supercomputers have been built with their processors immersed in liquid nitrogen, doubling processing power.

Dr Freeze

3 Cryosurgery can be used to remove early-stage cancerous and non-cancerous growths. A dab of liquid nitrogen totally kills the tumour without damaging any local tissue.

Cryo foods

Your freezer contains many goods that are flash frozen with liquid nitrogen-based processes. Cryogenics also supercools cookies in commercial bakeries.

Iced lice

Some pest-control companies are using carbon dioxide 'snow', a kind of foamy dry ice. The blast of snow kills bugs and eggs, and the non-toxic ice dissolves into gas, leaving no water damage.

DID YOUKNOW? Trumpets, saxophones and violin strings exposed to cryogenic temperatures are more resistant to wear



of matter at unnaturally low temperatures. The results have been revolutionary. Space flight was first made possible through the advent of liquid-propellant rocket engines powered by cryogenic fuels like liquid hydrogen and liquid oxygen. Not only do cryogenic fuels produce massive amounts of pressure and energy during combustion, but they can also be used in their liquid state to cool overheated rocket components.

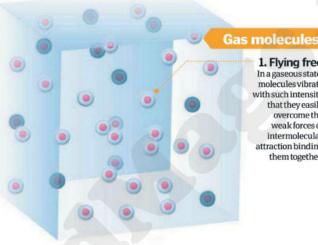
Semiconductors are another major cryogenic breakthrough. Certain metals and chemical compounds have been found to conduct electricity with nearly zero resistance or energy loss when cooled to cryogenic temperatures. The result is a hugely more efficient and effective way to generate and transport energy. Superconducting magnetsformed from coiled and cooled superconducting materials - are used to create the world's most powerful magnetic fields, like the one inside an MRI machine or the 1,232 dipole magnets that bend proton beams inside the Large Hadron Collider at CERN.

Cryogenics also provides a safe and effective way for preserving small samples of living tissue indefinitely without any cell damage. In fertility clinics, blood banks, hospitals and research labs, technicians routinely freeze sperm cells, egg cells, fertilised embryos, rare blood types, bacteria, viruses, plus plant seeds and tissue.

When the right precautions are taken, living cells stored at cryogenic temperatures enter a state of suspended animation, safe from cell death or deterioration. The biggest danger is ice

Cryogenics on a molecular level

Molecules are not that attractive. By that we mean that two adjacent molecules of the same element are held together by a weak attraction known in physics as Van der Waals' forces. As you raise the temperature (ie provide more energy), molecules vibrate with greater and greater intensity. When molecules get excited, they easily overcome the Van der Waals' forces trying to keep them together. This is the process that transforms solids into liquids and liquids into gases. But if you make the temperature really, really cold, those previously weak forces become so strong that molecules align themselves in a supertight formation, changing the molecular structure of solids into something much harder and even more stable.



1. Flying free In a gaseous state, moleculesvibrate with such intensity that they easily overcome the weak forces of intermolecular attraction binding them together.

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OKELVIN

Liquid molecules

2. High boiling point

As the temperature dips below 100°C (212°F), water molecules slow down enough to be drawn together by relatively strong intermolecular bonds, forming a liquid.

3. Frozen boiling point

Helium has such a weak intermolecular bond that it doesn't become a liquid until the temperature reaches -269°C (-452°F).

Solid molecules

4. No wiggle room

As the temperature descends below the freezing point, molecules are so strongly attracted to one another and become so tightly arranged that they cannot move, forming a solid material.

Cryogenically frozen

5. Cold attraction

Exposure to extreme cold will cause molecules to be so highly attracted to one another that it permanently realigns a material's micro-structure.

6. Stronger structure

After forging, steel contains stronger and weaker crystalline structures. Deep-freezing aligns more of the crystals as martensite, an ultra-hard form of steel.

TEMPERATURE SCALE

The hot and cold extremes and everything in between!

THE SUN Celsius: 5,727°C Fahrenheit: 10,340°F Kelvin: 6,000K

STAINLESS STEEL **MELTING POINT**

Celsius: 1,510°C Fahrenheit: 2,750°F Kelvin: 1,783K

BOILING WATER

Celsius: 100°C Fahrenheit: 212°F Kelvin: 373K

DEATH VALLEY

Celsius: 57°C Fahrenheit: 134°F Kelvin: 330K

NORMAL BODY TEMPERATURE

Celsius: 37°C Fahrenheit: 99°F Kelvin: 310K

ICE MELTS

Celsius: 0°C Fahrenheit: 32°F Kelvin: 273K

WATER FREEZES

Celsius: 0° Fahrenheit: 32°F Kelvin: 273K

ANTARCTICA

Celsius: -89.2°C Fahrenheit: -129°F Kelvin: 184K

CRYOGENIC FREEZING Celsius: -184°C

Fahrenheit: -299°F Kelvin: 89K



Celsius: -273°C Fahrenheit: -460°F Kelvin: oK

"Computer processors run twice as fast when bathed in liquid nitrogen"

The science of freezing

Formation inside and outside of cells. To prevent ice formation outside cells, the temperature is lowered slowly at a computer-controlled one degree Celsius (34 degrees Fahrenheit) per minute. To avoid deadly ice formation inside cell walls, meanwhile, technicians use osmosis to replace the water within cells with antifreeze solutions called cryoprotectants.

Sperm samples have been successfully thawed and used for in-vitro fertilisation after more than 20 years in the freezer and some cryobiologists estimate that properly frozen tissue can be stored undamaged for 1,000 years or more. In frozen zoos (see boxout) around the world, biologists are preserving sperm and embryo samples from thousands of endangered animal and plant species to create a 'Noah's Ark on ice' as a precaution against extinction.

Cryogenic temperatures have other unusual effects on electronics. Computer processors run twice as fast when bathed in liquid nitrogen and microwave radio receivers can detect the faintest signals from outer space when their components are super-cooled to cryogenic temperatures.

Devices known as SQUIDs (or superconducting quantum interference devices) are tiny magnetic field detectors with extreme sensitivity that might be used to create the first viable quantum computers. When cooled to near absolute zero, SQUIDs can detect the directional spin of individual electrons (up, down or somewhere in between). Like the 1s and os of a silicon transistor, quantum computers will use the relative position of infinite numbers of electrons to make calculations many millions of times faster than today's most powerful computers – all so long as they can keep their cool.





Cryogenic hardening

Picture an 18th-century blacksmith pounding a red-hot blade on an anvil, then dunking the metal into a bucket of water with a hiss. That's called quenching, and even before metallurgists knew what molecules were, they understood that rapid cooling makes metal stronger. In the Sixties, scientists discovered that if you lowered the temperature of stainless steel to -185 degrees Celsius (-301 degrees Fahrenheit), its molecules would be drawn together so tightly as to permanently alter the steel's molecular structure. After the steel is exposed to a cryogenic 'soak' for 24 hours, the temperature is slowly raised to 148 degrees Celsius (298 degrees Fahrenheit). As the molecules break free from their tight formation, they settle into a highly stable crystal structure called martensite that is up to 600 per cent more resistant to wear than untreated steel. Cryogenic hardening can greatly improve the life span of tools and industrial machine parts that undergo heavy stress.

Frozen wood frogs

Could this amphibian on ice provide the answers?

North American wood frogs survive the winter by freezing solid – with no heartbeat or brain activity – and thawing out in the spring unharmed. If humans are frozen, our cells suffer irreparable damage called frostbite. The wood frog protects its cells by injecting them with a glucose solution produced in its liver. The glucose acts as antifreeze, lowering the cells' freezing point.

But any water that exists outside of the cells – eg blood plasma is 90 per cent water – will freeze at its normal temperature (o degrees Celsius/32 degrees Fahrenheit), leaving the frog in a perfectly safe state of suspended animation. When temperatures rise, the water thaws first, slowly replacing the glucose in the cells, and the frog's heart starts pumping 20 minutes later.

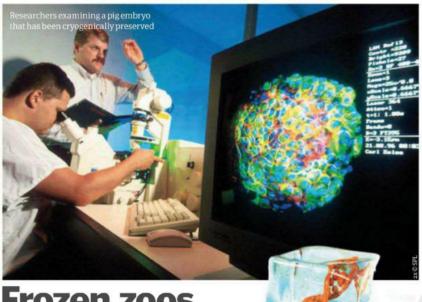


Check out our new site for a clip from BBC documentary *Inside A Frozen Zoo*

www.howitworksdaily.com



DID YOU KNOW? In March 1984, Zoe Leyland, Australia, became the first baby to be born from a thawed frozen human embryo



Frozen zoos

Is animal extinction now a thing of the past?

Cryogenic preservation is the closest thing we have to a time machine. Under controlled conditions, living tissue can be frozen in a state of suspended animation and revived undamaged after as many as two decades. Sperm and egg cells, as well as blood, DNA samples, viruses, bacteria and tissue samples are routinely preserved at cryogenic temperatures. The frozen zoo at San Diego Zoo, CA, contains 15,000 frozen sperm samples from 309 endangered species, some of which have been successfully paired with thawed egg cells to create viable test-tube embryos.

Ice is the greatest threat to cryogenic preservation. For living tissue to survive the process, it must be vitrified, meaning frozen without ice formation. Specimens are first treated with a cryoprotectant solution that

acts as antifreeze, lowering the freezing point inside the cell and halting ice formation around fragile cellular tissue. Secondly, specimens must be cooled slowly at a precise rate of one degree Celsius (34 degrees Fahrenheit) per minute to control ice formation between cells. Successful thawing and rejuvenation of living tissue has been limited to small samples, because cryoprotectants become toxicat higher doses. This is one of the greatest obstacles to cryonics - the freezing of entire bodies or brains in the hope that future scientists can 'cure' ageing and, perhaps, even death itself. While no living creature has been revived from cryogenic preservation, millions of babies have been born from in-vitro fertilisation (IVF) using frozen sperm, eggs and embryos.



CRYONICS The future of freezing humans

Small samples of human tissue and a few hardy organs have been successfully revived from cryogenic temperatures, but what about a whole human brain? Proponents of cryonics - cryogenic life extension - believe it's only a matter of time, and some careful preparation.

The trick is to preserve the brain of a deceased person before it suffers irreversible damage from oxygen deprivation. The instant the heart stops a team of medical attendants lowers the body into an ice-water bath and starts a heart-lung resuscitator. All blood and water is slowly replaced with an increasing concentration of

> cryoprotectant, which circulates into the brain. Fans blowing nitrogen gas lower the body's temperature to -125 degrees

Celsius (-193 degrees Fahrenheit), at which point all cell tissue is vitrified.

The brain is surgically removed and suspended in a storage tank of liquid nitrogen at -196 degrees Celsius (-321 degrees Fahrenheit). The greatest hope for revival lies with innovations in nanotechnology - employing an army of micro-machines to repair damaged tissue. Cryonics has its critics, but it wouldn't be the first time that theories dismissed as science fiction become science fact.

Will we one day be able to cheat death via cryonics?



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"By lowering the surface tension, the water can become more 'wet' and permeate clothes better"

Melanin / Washing agents

Skin colour explained

What is melanin and how does it affect the tone of our skin?



The light-absorbing pigment melanin is a chemical substance that gives your skin its natural colouring. Skin can vary from very dark brown to almost completely white due to a

combination of your genes and inherited traits and the amount of sunlight to which you're exposed.

Skin colour differs from person to person depending on the concentration of melanin present in their skin and its distribution throughout the skin's layers. Basically, those with less melanin have lighter skin, while those with more of the pigment have darker skin. Melanin is produced by specialised skin cells called melanocytes in the lower layers of the epidermis and is contained inside a melanosome by a very thin membrane.

Exposure to sunlight stimulates the production of melanin granules. The melanosomes containing the melanin then move out towards the skin's protective keratinocyte cells along branch cells called dendrites. Melanin is then stored in the nuclei of the keratinocytes where it acts as a natural protector against the effects of the Sun's ultraviolet rays. Keratinocytes make up the bulk – around 95 per cent – of the outer layers of the skin and form the barrier between the body and the outside world. They take up melanin which can absorb cancer-causing UV radiation so it doesn't get into the body's internal tissues.

Keratinocytes

These protective cells are produced in the lower layers of the epidermis. They take up the melanosomes produced by the melanocytes.



Melanocyte

Melanin is made in the melanocytes.
People with darker skin, or those
who live in regions with greater
sunlight exposure, have more
active melanocytes.

These packets of melanin release melanin granules into the keratinocytes.

Surface

Basal skin cells manufactured in the lower layers of the epidermis grow through the skin to the surface, where they are eventually sloughed away.

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Dendrite

These branching cells pass

melanin to keratinocytes.

Melanin and skin colour

Keratinocytes

The keratinocytes of lighterskinned people take up fewer melanosomes.



Melanocyte

Those with lighter skin have fewer dendrites in their lower layers and their melanocytes are also less active.

Melanosomes

The melanosomes in lighter skin release far fewer melanin granules.



Washing detergents

Discover the chemistry at work inside your washing machine



Anionic surfactants are the workhorse ingredients of most washing detergents. They are compounds such as sodium alkyl sulphate and are made up of molecules that have opposite charges at different points (polar molecules).

Water is also made of polar molecules and, when mixed with washing detergent, the hydrophilic (water-loving) part of the surfactant molecule attracts to the water molecule, while the hydrophobic (water-hating) part of the molecule adheres to the dirt and grease in your clothes. This makes the dirt and grime more soluble in the water, allowing for easier removal from your clothing.

Another cleaning effect surfactants have is to lower the surface tension of water. Surface tension is created by these polar molecules pulling on one another due to their charge. This accounts for how pond skaters walk on water and why beads of water hang suspended on grass. By lowering the surface tension, the water can become more 'wet' and permeate clothes better allowing for a deeper clean.



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ltmuseum.co.uk

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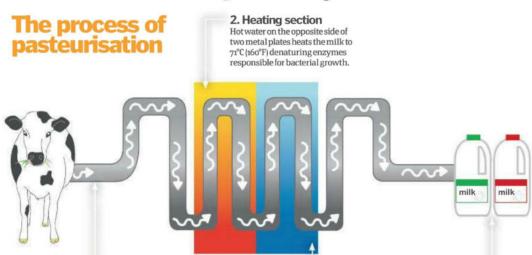
london transport museum

"Photons are responsible for one of the fundamental forces of nature – the electromagnetic force"

Pasteurisation / Photons

How pasteurisation works

Find out how pasteurising food increases the shelf life of many products



1. Fresh milk in

Cold raw milk is drawn into the regenerator section of the pasteuriser for heating.

3. Cooling section

Warm milk passes through two plates where a coolant on the opposite side of the metal plates chills the milk to below 4° C (39°F).

4. Pasteurised milk out

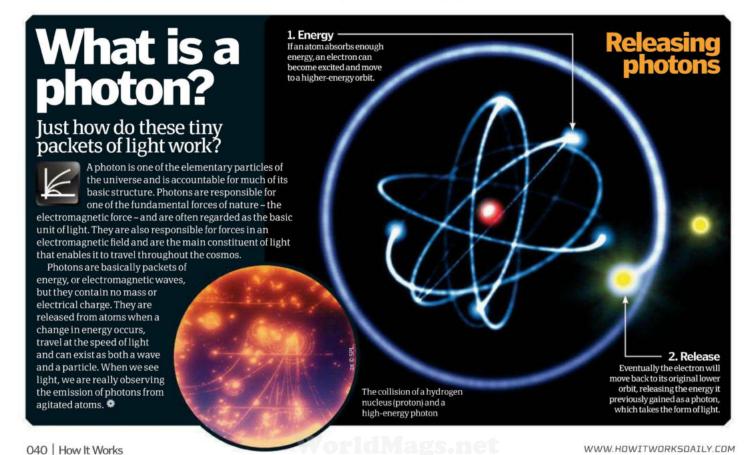
The pasteurised milk is then sent to a cooled storage tank for packaging and later distribution.



Pasteurisation is a process of heating food and liquid to a specific temperature in order to slow microbial

growth, essentially giving it a longer shelf life. This technique is usually associated with milk where it reduces the number of potentially harmful bacteria such as E coli and salmonella that are present in its raw state.

Bacteria produce enzymes which help them to break down and digest a wide range of organic materials allowing them to divide and conquer. Heating milk to 71 degrees Celsius (160 degrees Fahrenheit) for 15 seconds changes the shape of the enzymes in the harmful bacteria, rendering them useless and hindering the bacterial growth and multiplication process. Pasteurisation does not stop all the bacteria, which is why you still need to keep it in the fridge. It does, however, significantly lower the concentration of harmful bacteria, leaving your stomach to do the rest of the work.





WIT N Watch a video of the Tsar Bomba being detonated at How It Works Daily

www.howitworksdaily.com



DID YOU KNOW? The biggest nuclear weapon ever detonated was the Tsar Bomba in 1961, with a yield of 50 megatons of TNT

How does a mushroom cloud form?

What's the science behind these oddly shaped clouds?



Mushroom clouds are usually the result of a colossal explosion, such as that produced from a nuclear weapon or another type of large explosive device. Mushroom clouds can tower many miles

in the sky, but they will flatten out around the stratosphere, hence how they acquired their name.

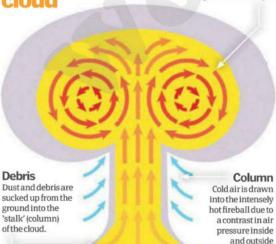
When an atom bomb is dropped, it doesn't explode on the ground. Instead, it's detonated several hundred metres above land to maximise the blast impact. This creates a fireball of superhot gases in the air within a split second of the explosion that can be several miles wide. This intensely hot ball draws up debris from the ground as the air pressure inside is much lower than that outside. The ball of fire rises upwards as the head of the mushroom cloud, carrying a column of dust and debris in its wake. It eventually reaches a point where the air is thinner - the stratosphere - causing the head to flatten out. The fire spreads out in all directions and convection currents form inside the head. These currents force the edges of the head to curl downwards and rejoin the central column, giving the appearance of a traditional toadstool or mushroom.

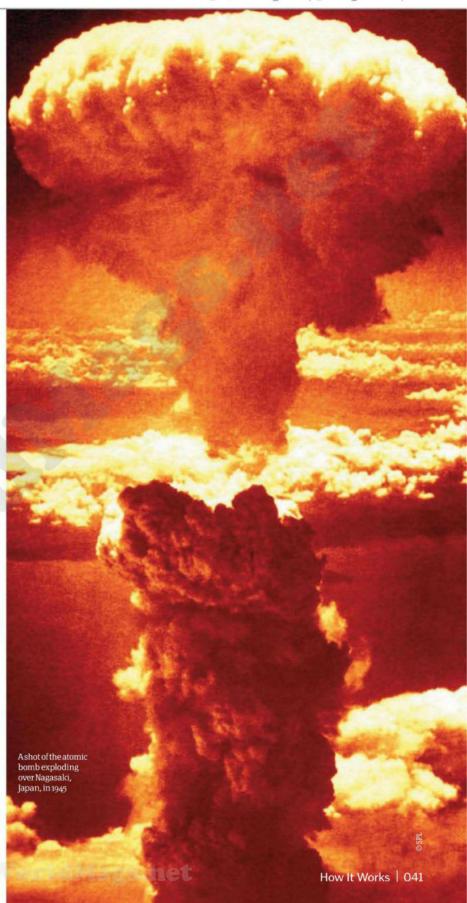
Mushroom clouds generally only form as the consequence of a large manmade or natural explosion, such as a volcanic eruption, however they have been recorded to occur in much smaller explosions on Earth too, such as after the firing of a cannon. In the case of a volcanic eruption, the enormous amount of heat created at the peak of the volcano takes the place of the fireball in the atom bomb scenario.

Convection

the explosion.

At the top of the cloud convection currents form, bringing the hot gas round in a circle back into the central column and creating a toadstool shape.







Weight-loss surgery

How do gastric bands work?

Gastric bands
only work in
conjunction
with a strict
diet plan

Gastric bands aren't just for cosmetic purposes – they can help to prevent health problems too

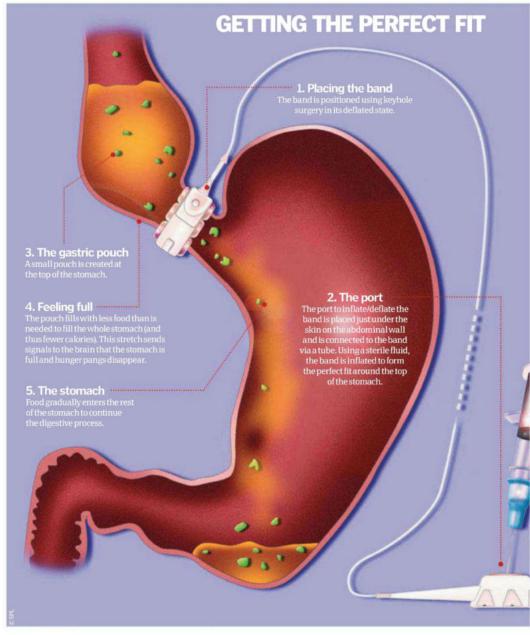
Gastric bands are inflatable circular balloons that are placed around the top of the stomach. They reduce the total capacity of the sack-like organ, so when the patient eats, their stomach wall stretches sooner and tells their brain that they are full, but with a smaller volume of food. This leads to a lower daily calorific intake and, as part of a controlled diet and exercise regime, results in weight loss.

The band is typically placed with keyhole (or laparoscopic) surgery, leading to smaller scars, less pain and a shorter hospital stay. However, patients first need a vigorous workout. They must try and lose weight through conventional methods and medications, which may take up to six months. All patients undergoing weight-loss surgery must see a health psychologist too. The patients should be mentally prepared and positive that a gastric band will help them slim down as part of a holistic approach – for example, it won't work if they continue to eat pizza and chips at every meal!

The band is placed in position in its deflated state. Through a port placed just under the skin, its size can be adjusted incrementally, leading to a controlled rate of weight loss; uncontrolled, over-quick weight loss can be very dangerous.

As with any medical procedure, there are potential risks and complications. The band can slip or become too tight around the stomach, leading to pain and visits to the emergency department. In these circumstances, deflating the band through the port beneath the skin solves most problems in the short term.

"[Patients] must try and lose weight through conventional methods and medications, which may take up to six months'





History

The first non-adjustable band, made of a permanent mesh, was used in the Seventies. It wasn't until the early-Nineties, with the arrival of keyhole surgery, that adjustable bands became common.

At any rate...

2 Most experts agree that weight loss of approximately 1kg (2.2lb) a week is safe any faster than this and you can risk dangerous metabolic side-effects.

Extra treatment

3 Although gastric bands are successful in most patients, in some they will have no effect. Around a third of patients will need a further procedure related to the band.

Be a patient patient

Gastric band surgery doesn't work immediately and can take up to 12 months to take effect; this is in contrast to a sleeve gastrectomy or bypass operation, which work immediately but are more invasive.

Up in the air

Most surgeons recommend deflating the band by half before flying. If it's full, any trapped air bubbles can expand and cause painful excessive restriction.

DIDYOUKNOW? The first adjustable gastric band was patented by Dr Dag Hallberg in Sweden in 1985



How healthy are you?

The body mass index (BMI) is commonly used to estimate a person's body fat. It is utilised around the globe, including by the World Health Organisation. It estimates a person's body size by dividing their weight by their height squared (ie BMI = weight in kilograms/ height in metres squared). The advantages are that it is easy to use, is the same for males and females and, in adults, is age independent. In children, it is used slightly differently and correct values vary according to age.

The BMI reading corresponds to categories of underweight, normal, overweight and obese.

The disadvantage of the BMI system is that it doesn't take into account people's differing body proportions or muscle bulk. Athletes with lots of muscle, for example, would be classified as being overweight and thus unhealthy, although they're probably very fit. Some children who grow at different rates may be classed as outside normal ranges too, whereas they are in fact just in a growth spurt. That's why BMI must be used in conjunction with the person's overall fitness and appearance, and should be measured at several points over time to detect trends.



What's the alternative?

All patients should start with a regime of healthy eating and exercise before considering surgery. Medications should be tried next and, combined with the right lifestyle, most people will lose weight and regain their health. However, some people don't manage to lose weight, despite trying hard, so surgery is the only option left.

An alternative to the gastric band is the sleeve gastrectomy. During this procedure, most of the stomach is removed, leaving a sleeve-shaped tube. In a similar way to gastric bands, the patient feels full sooner, reducing the calorific intake. Gastric bands are not permanent and can be removed, but they can also slip out of place. Sleeve gastrectomies are permanent and won't dislodge, but the procedure is more invasive and there are other potential complications that will need to be discussed thoroughly with the surgeon.

During a gastric bypass, on the other hand, a small pouch of the stomach is created which is connected to the small intestine lower down. This has a malabsorption effect, which ultimately means that fewer calories from what is ingested are taken into the body.

There are other forms of intervention. such as intragastric balloons, but not enough evidence exists to assess them properly. Finally, abdominoplasty (a 'tummy tuck') is a quick way to get rid of some excess abdominal fat without changing anything inside; this is purely cosmetic surgery though and has no internal health benefits.

HOW DOES OBESITY AFFECT YOU INSIDE Gastric bands don't just make people look better. There

are serious consequences of obesity on the internal organs, which have health implications that are very expensive to treat. Thus gastric bands can improve health and be cost-effective in the long term.

The heart

Obesity reflects underlying high-circulating triglycerides and poor health. This 'circulating fat' can block the coronary arteries, leading to angina or heart attacks (myocardial infarctions).

The lungs

When obese people have a layer of fat sitting on their chest wall, combined with fat from the abdomen preventing complete expansion of the lungs, it can lead to breathing problems. This is worse at night when lying flat and can cause sleep apnoea, where all breathing stops.

The abdominal wall

Everyone has a fatty layer on their abdominal wall. In obesity, this is often larger and it reflects what's going on inside too.

The muscles

Everyone has rectus abdominis (six-pack) muscles, even if they're buried between layers of fatty adipose tissue.

The liver

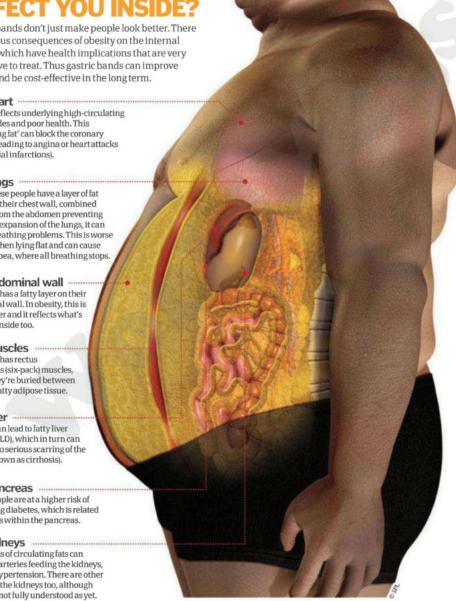
Obesity can lead to fatty liver disease (FLD), which in turn can progress to serious scarring of the organ (known as cirrhosis).

The pancreas

Obese people are at a higher risk of developing diabetes, which is related to changes within the pancreas.

The kidneys

High levels of circulating fats can block the arteries feeding the kidneys, causing hypertension. There are other effects on the kidneys too, although these are not fully understood as yet.

















Nature's most toxic



Environment

Our big Environment feature this month is looking at some of the most noxious creatures. you can find in the animal kingdom. From reptiles to arachnids to mammals, we reveal exactly how lethal they are with our 'deadly rating' and how they put their complex biological weapon to good use. Elsewhere we look in depth at the anatomy of trees and why sometimes we are able to see two rainbows at once. Finally, you can wise up on one of the planet's finest birds of prey, the owl.



49 Double rainbows



50 Beluga whales



52 Owls

ENVIRONMENT

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DEA

It's the tiniest bite that does the most damage. Find out how these poisonous predators bring pain and paralysis on their prey



Venom is a force multiplier. It allows small animals to tackle prey that approach or even exceed their own body size. Killing your prey with brute strength alone requires a

large body, which in turn means that you need to catch more food to sustain it. Venom enables a predator to make a single strike from ambush and completely incapacitate its victim in less than five seconds. This is much more energy efficient than a prolonged tussle and eliminates the risk of injury to the predator.

Most venom is secreted by modified salivary glands. Ordinary saliva already contains digestive enzymes to begin breaking down food before it reaches the stomach. Venom probably first evolved in animals that killed their prey with a bite and then injected saliva to 'marinade' the meat so that it was easier to consume. After that, natural selection would favour those animals with evermore potent combinations of enzymes until the saliva itself did enough damage to kill the prey. Modern venom is often a cocktail of hundreds of different enzymes and peptides. As well as digestive enzymes, most species also include specific compounds that block the transmission of nerve impulses; this causes paralysis and suffocation.

Of course, while venomous animals are continuously evolving new toxins, their prey are also frantically evolving venom resistance. To counter this, most animals inject vastly more than the minimum lethal dose of venom with each bite. This guarantees the kill and also hastens it, which stops the victim from escaping to die alone, or injuring the predator.

Venom is less effective against large animals because of the time it takes to spread through the body, so larger animals are less likely to be venomous. The main exception to this is snakes, which use venom to compensate for their lack of claws to hold struggling prey in place. There are about 650 venomous species of snake but only a few venomous lizards.



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Head NOXIOUS NATURE



1. Yellow-bellied sea snake

venom more toxic than any and snake, which causes nuscle breakdown, renal failure and cardiac arrest

Proboscis

Geography cone snail

SPEED: Slow-moving but with a

Low. Relies on immobilising

AGGRESSION: High. Cone snails will normally sting

anyone that picks them up. INTELLIGENCE: Low. Molluscs hunt by smell and instinct.

lightning-fast sting.

prev before eating it.

DEADLY RATING:

This flexible tentacle



2. Lonomia moth caterpillar

Brushing past a group of them can cause inner haemorrhagin



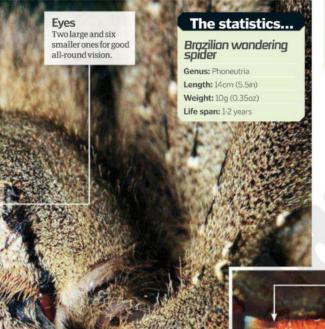
3. Box jellyfish

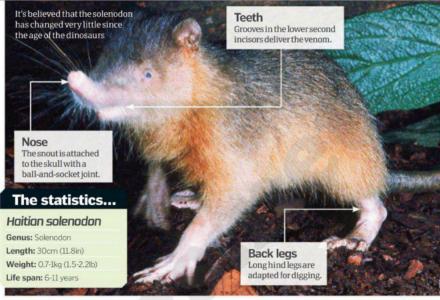
Virtually transparent a carrying around half a tentacle, the box iellyfish is one of the deadliest

DIDYOUKNOW? Although the inland taipan is the world's most venomous snake, there's no recorded case of a human fatality

BRAZILIAN WANDERING SPIDER

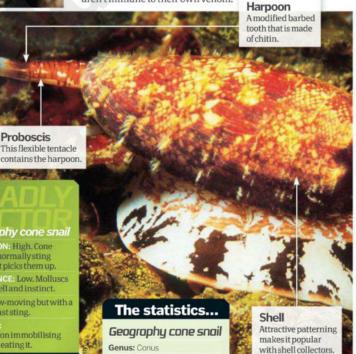
Wandering spiders do not spin webs. They stalk the forest floor at night and attack anything they come across, from insects to mice. In the day they hide somewhere dark and moist and this can bring them into contact with humans as they are often found near houses or in bunches of bananas. The Brazilian wandering spider has the deadliest venom of any spider - a neurotoxin two to five times more toxic than the black widow's. The relatively low fatality rate of victims is thought to be partly because the spider will often 'dry bite' to conserve venom. Bites cause instant, intense local pain and swelling, followed by irregular heart rhythm, vomiting and internal haemorrhaging.





HAITIAN SOLENODON

Solenodons are related to the shrew but much larger - about the size of a hedgehog. The word solenodon means 'slotted tooth' in Greek and these slots, or grooves, are used to inject the venomous saliva into their prey. They evolved on the islands of the Caribbean, without any natural predators. The introduction of cats and dogs has left them extinct everywhere except for Cuba and Hispaniola. The Haitian, or Hispaniolan, solenodon is the more aggressive of the two and will attack without provocation. In the wild they eat earthworms and insects, as well as the occasional frog or lizard. Their venom is not lethal to humans but, in smaller animals, it causes paralysis, convulsions, bulging eyeballs and death. Interestingly, solenodons aren't immune to their own venom.



Length: 15cm (5.9in)

Weight: 300g (10.6oz) Life span: Unknown

Haitian solenodon

High. Evolved without natural predators and shows no fear.

A mammal's brain makes this one shrewd shrew.

SPEED: Slow. Solenodons run in an awkward zigzag pattern.

STRENGTH: High. Solenodons have been known to tear a chicken to pied

DEADLY RATING:



GEOGRAPHY CONE SNAIL

There are over 600 species of cone snail and all of them are venomous. Cone snails deliver their venom using a thin harpoon made from a modified tooth. This is fired from a flexible proboscis that enables the snail to fire in any direction, even directly behind it; this means that there is no safe way to pick up this gastropod. The venom of the cone snail contains over 200 different compounds that can paralyse a small fish in less than two seconds. The geography cone is a particularly large and venomous species. It can deliver enough venom to kill 15 humans in a single sting. There is no antidote; medical care consists of just treating the symptoms until the venom is metabolised.

Front legs These are lifted up when

threatened to reveal some

warning stripes beneath.

"Blue-ringed octopus venom is 10,000 times more toxic than cyanide"

Nature's most toxic



BLUE POISON ARROW FROG

The bright colours warn of The most toxic species can kill a human after one brief touch.



SLOW LORIS

This sleepy creature has a special gland on each arm that it licks to give itself a toxic bite. Mothers also lick the fur of their young to deter predators.



DUCK-BILLED PLATYPUS

The male platypus has a sharp spur on its hind legs. The venom isn't powerful enough to kill a human but it can cause excruciating pain



Its diet of beetles provides a

ANSWER: THEY ALL ARE!

BLUE-RINGED OCTOPUS

Although one of the smallest octopuses this is easily the most lethal. The main ingredient in its venom is tetrodotoxin, which is 10,000 times more toxic than cyanide. Tetrodotoxin is found in many other venomous animals, including cone snails, but it's present in much higher concentrations in blue-ringed octopus venom. Bites are tiny and almost painless but, within ten minutes, the venom blocks the action of all the nerves that control the muscles. General paralysis and breathing difficulty ensue, but because the venom can't cross the blood-brain barrier, the victim remains aware throughout. The paralysis even results in fixed, dilated pupils and rescuers may give up resuscitation attempts while the victim is still alive and conscious.



AGGRESSION: Docile. Will only attack if provoked or stepped on.

INTELLIGENCE: High. Can solve mazes and imitate its surroundings.

SPEED: Moderate. Uses jet propulsion for extra speed when making a getaway.

STRENGTH: Moderate. Powerful, muscular tentacles but small overall size



The statistics...





The scorpion's Latin name leiurus quinquestriatus translates as 'five stripes'.

COMPANY OF THE PARTY OF THE PAR Thin yellow skin

The deathstalker prefers at least 40 per cent humidity. STORY CO. C. C.

Rings

The characteristic blue rings are only displayed when threatened

Tentacles

Each one has its own mini-brain and is semi-autonomous.

The statistics...

Blue-ringed octopus

Genus: Hapalochlaena Length: 15cm (5.9in)

Weight: 28g (loz)

Life span: 2 years



Beak

Made of keratin. The

We pinpoint the home turf of some of the toxic beasties featured in this article

Haitian solenodon

Continent: North America Countries: Haiti, Dominican Republic Notable region: Hispaniola

Brazilian wandering spider

Continent: South America Countries: Costa Rica to Argentina Notable region: Brazilian Amazon

Deathstalker scorpion

Continent: Africa Countries: Egypt, Libya, Chad, Niger, Mali Notable region: Edges of the Sahara Desert

Inland taipan

Continent: Oceania Countries: Australia Notable region: Western Queensland

Different strokes

Bees and wasps look similar but strike in different ways. Bee venom is acidic, to cause pain and drive attackers away. Parasitic wasps, meanwhile, use a neurotoxin to paralyse their host.

Small but deadly

2 Baby inland taipans are actually more lethal than adults as they haven't yet learned to regulate their venom dose so will inject their entire supply with a single bite.

Painless stinger

Cone shell toxin contains a compound that is 100-1.000 times more effective than morphine as an anaesthetic. This helps to calm prey so they don't struggle too much.

Poisoner by proxy

The blue-ringed octopus doesn't even need to bite to poison you: the venom can be absorbed directly through the skin so even swimming near one can result in mild symptoms.

Stiff medicine

5 One unusual side-effect of a bite from the Brazilian wandering spider is that the venom causes acute and painful erections in men that can last for hours.

KNOW? In 2005, a chef in Somerset, UK, bitten by a Brazilian wandering spider only survived after a week in hospital



Continents: Oceania/Asia Countries: Japan, Australia, Indonesia Notable region: Southern New South Wales

Geography cone snail Continent: Oceania

Countries: Australia Notable region: Northern coast of Australia in fact, it is one of the most deadly substances of any kind. At least 40 times more powerful than the venom of a cobra, the lethal dose for a typical adult human is calculated to be around two milligrams; that's about as much as the blood you lose from a mosquito bite. A typical bite injects enough venom to kill 25 humans, or a quarter of a million mice! Fortunately, the inland taipan lives in extremely remote parts of central Australia where it very rarely comes into contact with people. For such a deadly creature, it is also very shy and, despite its other name the fierce snake, it never attacks unprovoked.

BOX JELLYFISH Found in the waters of northern Australia, the box jellyfish has one of the most deadly venoms in the world. It attacks

Nature has plenty more

toxic creatures – here are just a few...

MOST PAINFUL VENOM



BLACK MAMBA

A native of eastern Africa, this long, highly venomous snake (actually brown in colour) can inject a whole bunch of nasty neurotoxins and cardiotoxins

AFRICA'S MOST VENOMOUS SNAKE



Not to be mistaken for a lump of coral, the stonefish delivers powerful neurotoxins from its dorsal spines; in fact, some think it's the most venomous fish in the world.

MOST VENOMOUS FISH



FUNNEL-WEB SPIDER

Unlike most other venomous spiders, the venom of the male funnel-web is more deadly than that of the female. These

AUSTRALIA'S MOST FEARED

The statistics...

Inland taipan

Genus: Oxyuranus

Length: 1.8-2.5m (5.9-8.2ft)

Weight: 6kg (13.2lb)

Life span: 10-15 years

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INSIDE

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Head to our site for an amusing video of someone seeing a double rainbow

v w w . h o w i t w o r k s d a i l y . c o m



DID YOU KNOW? The dark band between double rainbows is named after Alexander of Aphrodisias who mentions it in 200 CE



Double rainbows What causes this colourful meteorological phenomenon?



Regular rainbows occur when moisture in the air – commonly rain, but also mist or spray such as that from a waterfall – refracts sunlight in such a way that it

is broken up into its constituent colours.

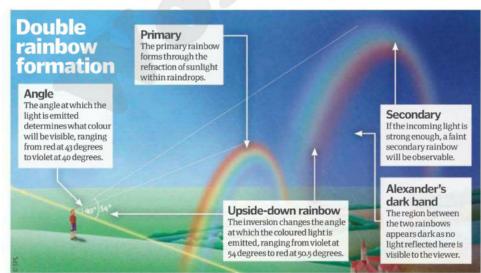
The phenomenon occurs when the Sun is positioned behind you and sunlight passes through the airborne water. The light refracts (bends) inside the droplets and the white light is broken up. Each colour has a different wavelength so, depending on

the angle of refraction, a different colour of light will be reflected outwards; the result of this process is what we observe when we see a rainbow.

Every rainbow is accompanied by another, secondary rainbow, but it's usually too dim to see. This double rainbow effect is due to the continued reflection of light inside each water drop. Sunlight is actually reflected twice inside a drop: once to produce the primary rainbow and a second time at the back of the drop. This second reflection inverts

the light but undergoes the same refraction, so exits in the same way as before – though upside down.

This second reflection reduces the intensity of the sunlight, but it also produces a second inverted rainbow, creating a double arc of multicoloured light in the sky. Interestingly, sunlight can reflect many more times inside a water drop so many more rainbows (three, four or even more) can be produced, but the incoming light is rarely strong enough for these to be visible by the naked eye.





"Every rainbow is accompanied by another secondary one, but it's usually too dim to see" "Belugas don't have fused neck bones so are the only whales capable of turning their heads"

Artificial horticulture / Mie scattering / White whales



What is hydroponics?

How the natural world can be replicated to grow plants



To grow, plants generally need a combination of water, sunlight, carbon dioxide and nutrients. Through photosynthesis they convert these four basic elements into sugars and oxygen, allowing them to survive, grow and

reproduce. Hydroponics is the practice of growing plants by artificially supplying them with these four things in the absence of natural sources. This process means the plants can be grown in an interior environment with neither sunlight nor soil. Artificial lights are often used instead of the Sun to enable the plants to produce chlorophyll, while oxygen, water and minerals are transported to the roots directly through a series of tubes. In this manner the plants are able to grow in exactly the same way as they would if they were outside in their natural habitat.

Hydroponics is very useful as it enables different plants to be grown en masse in adverse conditions where they would otherwise perish, such as in hot or cold climates. The absence of soil also largely removes the intrusion of insects and weeds, which can hamper growth. This artificial growing technique has also been considered for use on other planets.

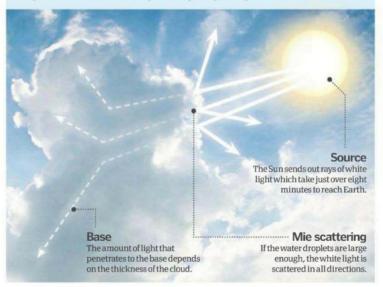
Why are clouds white?

Discover the basic scientific principle that makes clouds white



Clouds are formed when humid air, or water vapour, rises and cools. The vapour expands and becomes tiny droplets. Clouds only get their white appearance if these droplets become large enough to scatter visible light in all directions; this is known as Mie scattering.

Visible light is a form of electromagnetic radiation, with each different colour that we can see having a different wavelength. White light, however, contains equal amounts of all colours of the spectrum. When sunlight hits the individual water droplets in a cloud all wavelengths of light are scattered evenly in all directions. However, very thick clouds, which are made of very densely packed water droplets, will appear darker – like storm clouds – because less of the incoming light from the Sun can penetrate to the base. From above in an aeroplane, though, a storm cloud will still appear white – it only looks dark from the ground because little sunlight is not getting through.





How do beluga whales moult?

What makes these white whales so well adapted to Arctic waters?



Belugas, also known as white whales, are carnivorous mammals that are found in and around the Arctic coastal regions of Europe, Asia and North America. Beluga whale skin is grey at birth (as it serves as better camouflage) and

gradually becomes lighter till at around the age of five it becomes creamy white, giving them their unique appearance.

To keep them warm during the freezing Arctic winters, the belugas have extremely thick insulating skin – 100 times thicker than human skin. In the summer months, however, belugas take part in an unusual custom whereby they group together in pods and head for the shallow fresh waters of river estuaries to moult. Once in the shallows, the groups roll around on the mud and rocks to wear away the dead skin.

Unlike other whales, belugas don't have fused neck bones and so they are the only whales capable of turning their heads.

Broadleaves

Most trees are 'broadleaves' with large, flat, veined leaves. These can be simple (growing individually at the end of a single stalk) or compound (consisting of a group of leaflets).

Deciduous

2 Many broadleaves are deciduous, shedding their leaves in the autumn. This enables them to conserve energy throughout winter when sunlight is limited.

Antifreeze resin

To survive the winter, evergreen trees produce a sticky resin that acts like antifreeze. This prevents the leaf cells from crystallising, which would otherwise cause cell damage.

Fighting pollution

As well as producing oxygen, trees can also rid the soil of certain chemicals by storing them or breaking them down into harmless substances; this is called phytoremediation.

The treeline

This imaginary line represents the height above which trees cannot grow due to adverse conditions. The highest treeline is in Bolivia at 5,200m (17,060ft) and the lowest is in Sweden at 650m (2,133ft).

DIDYOUKNOW? Most conifers are evergreen and only replace their needle-like leaves when necessary

How trees

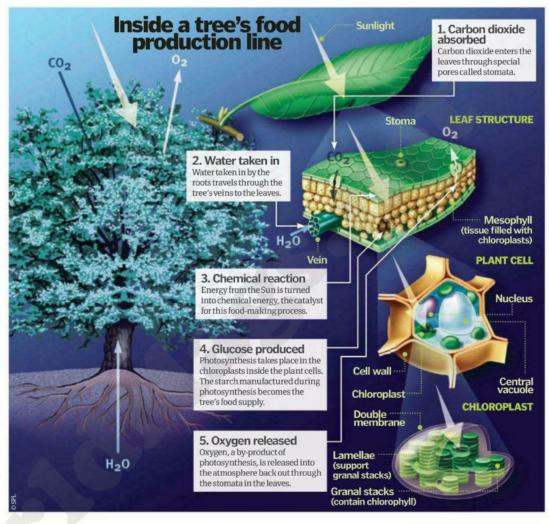
How do these large plants grow, nourish themselves and provide oxygen for us?



Trees are oversized plants that become so big that they require a woody stem to support their weight. Not only

are they attractive to have in your garden, but they're also amazing natural air filters, capable of absorbing harmful carbon dioxide and turning it into oxygen. They also clean the soil, provide habitats for wildlife, muffle noise pollution and prevent soil erosion.

Like all plants, trees harness energy from the Sun to convert carbon dioxide and water into glucose and oxygen. Sunlight is the catalyst for photosynthesis, which takes place within the plant's cells, inside structures called chloroplasts. If you look at a leaf under a microscope it's possible to see the tiny chloroplasts, which are green due to chlorophyll - this green pigment is vital as it traps the energy which powers photosynthesis.



Trunk structure

One of the main differences between flowering plants and trees is the woody stem. You can tell a lot from looking at the cross-section of a tree trunk, including its age and past environmental conditions.

Growth rings

Thick rings indicate excellent growth conditions (eg plenty of water), while thin rings suggest a lack of nutrition. By counting the rings you can calculate the number of seasons (or years) a tree has lived.

Wood ray

This passageway enables nutrients and water to be distributed horizontally through the trunk from pith to phloem.

Heartwood

This darker layer, which surrounds the core of the trunk (the pith), consists of dead sapwood to support the weight of the trunk and branches.

Sapwood

Often paler than the rest of the trunk, the sapwood is the living wood inside a trunk. This layer containing structural xylem is capable of transporting raw sap to the leaves.



The pith is the relatively soft, nutrient-rich tissue that makes up the core of the trunk and helps promote sapling growth.

Phloem

Just below the bark is the phloem, a tissue that transports sap and glucose produced by photosynthesis up and down the tree.

Bark

This fibrous outer layer consists of hardened dead cells that protect the trunk from harmful external forces.

Cambium layer

This tissue layer contains active cells that constantly divide, enabling outward growth that increases the trunk's diameter. The new cells produced form the ring markings, which tell us more about the tree from season to season.

How do trees manage to stay hydrated?

In order to obtain water for photosynthesis, the tree's root hairs absorb moisture from the soil, entering tubular xylem cells through a process called osmosis. Because water is constantly evaporating from the leaves at the top of the tree (a process called transpiration), negative pressure is created in the xylem, which draws water up into the cells from below. The xylem tissues in the trunk are rigid. A tree's internal transport system enables water, food and other nutrients to be delivered to all parts of the tree, much like arteries and capillaries in the human body.

"Super-sensitive hearing helps the owl pick up on the gentle rustling of small-footed prey"

How owls hunt

Discover what makes this nocturnal bird of prey such a superior predator

The owl has evolved a number of traits that make it a masterful sky hunter. As well as being a keen territorial predator, with an intimate knowledge of the local terrain, the owl also has a number of physical characteristics that make it a formidable aerial assassin. Features include powerful talons, a sharp, hooked beak for rending flesh from bone plus heightened senses for locating and homing in on prey from above.

Super-sensitive hearing helps the owl pick up on the gentle rustling of small-footed prey such as birds, rodents and frogs far below. The extra-large disc-like shape of an owl's face with a ridge of feathers down the middle further improves hearing as sound waves are collected and channelled outwards towards the ears.

While we humans can hear sounds on a horizontal plane – ie we have the ability to tell whether a sound came from the left or right by turning our head in a particular direction to focus on the location of a sound, owls can hear things on a vertical plane. Species like the great horned owl, for example, have lopsided ears – with the left ear positioned slightly higher than the right, enabling them to accurately detect whether a sound originated from above or below.

Unlike the majority of other bird species, whose eyes are positioned on the sides of their heads, owls have front-facing eyes, giving them binocular vision and depth perception. This helps them get a fix on their quarry. They cannot, however, move their eyes in the sockets; instead they have the ability to turn their entire head some 270 degrees. This means they do not have to move the rest of their body to see what's going on behind them, which helps the birds to stay quiet. It's the ability to remain silent that gives an owl its greatest advantage when hunting.



DID YOU KNOW?



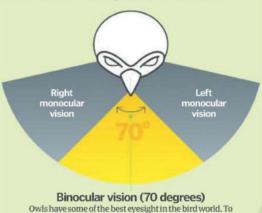
Dive-bombing owls

While owls remain generally out of sight during the day, there are occasional reports of them exhibiting aggressive behaviour, attacking or dive-bombing animals many times their size, including domestic dogs and even humans. Rather than attempting to kill and eat said humans, they are in fact defending their territory, mates, nests and/or chicks.

DIDYOUKNOW? According to the Guinness World Records, the newest bird of prey is the Socotra buzzard, discovered in 2010

Seeing is believing

Owls have forward-facing eyes, like humans, and so this means they can see an object with both eyes at the same time. That is, their vision is binocular, as opposed to the monocular vision of most other birds whose eyes are located on the sides of their heads. As you can see from this diagram, owls have a wide field of view - around 110 degrees - but only about 70 degrees of this are binocular.



put it into context, humans have an 18o-degree field of

vision, 140 degrees of which are binocular.





What are pellets?

You can discover a lot about what an owl eats from the pellets it spits out. These pellets contain the indigestible parts of an owl's diet. Birds of prey eat rodents and small birds. However, because they don't have teeth and cannot chew their food. they have to swallow things whole - that includes any fur, bones, feathers, claws and teeth. While other birds have a special organ called a crop, which is used for storing food for digestion later, owls do not have one of these. Instead, when an owl consumes food, it passes into the muscular gizzard called the ventriculus, a kind of secondary stomach full of small stones. The stones help to grind up the digestible food (which includes muscle, skin and organs) and digestive enzymes and acids dissolve the food so it can pass into the intestines. The leftover rubbish, which can't be broken down, is squeezed by the muscles of the gizzard and compacted into a soft pellet to be expelled from the body after many hours. The owl cannot eat again until the pellet has been coughed up, or regurgitated.



Hunters of the Sky, brought to Longleat Park by the Hawk Conservancy Trust, will be returning in 2012 with a new birds of prey show. This spectacular display of eagles, kites, vultures and owls will fill the skies over Longleat; this is family fun at its very best! Open weekends only: 25 February-18 March. Open daily: 24 March-4 November. For more information on Longleat Safari & Adventure Park visit www.longleat.co.uk.



Interview Jimmy Robinson

Hawk Conservancy Trust curator Jimmy runs the 'Hunters of the Sky' bird of prey display at Longleat

How It Works: What do owls like to eat? Jimmy Robinson: Owls will eat a variety of different prey, normally depending on the size of the owl and where it lives. A barn owl mainly feeds on rodents while eagle owls will take prey like rabbits and even foxes on rare occasions.

HIW: What is the owl's most effective method/ tactic for hunting down this kind of prey?

JR: Many owls have silent flight. This is thanks to a comb-like edge to their flight feathers allowing air to pass through them; this reduces the noise of its flapping wings.

HIW: At what age is a young owl old enough to attempt its first kill?

JR: At about four months old owls are catching prey for themselves. Some small species are fully feathered at ten weeks old. They grow up at an alarming rate and, once feathered, the race is on to be hunting as quickly and successfully as possible. In the wild it's survival of the fittest.

HIW: How and where do owls make their nests? JR: Owls nest in many different places. Barn owls

nest in farm buildings or artificial nest boxes purposely put up to help them. Snowy owls, on the other hand, nest on the ground, while some species take over nests from other birds like crows.

HIW: What do owls do all day? How are they protected from predators? JR: Many owls are very well camouflaged. During the day the nocturnal owls will roost in a high tree or suitable safe place away from prying eyes.

HIW: What are the owl's main natural predators? JR: Other birds of prey, carnivorous mammals and reptiles like snakes will all look at owls as a suitable meal.

HIW: Do owls live up to their wise reputation?

JR: Owls have incredibly large eves: this enables them to see at night very well, but it does mean that the eyes take up much of the skull, leaving little room for the brain. Owls are not dim-witted, by any means, but are certainly not as wise as we're led to believe. There are many links to birds of prey and Greek deities; in fact, the little owl's Latin name links it to Athena, who was known as the goddess of wisdom.







This month in **Transport**

Formula One might be the first thing that springs to mind when you think of motorsport, but there's a world of racing beyond this. In our six-page feature we explore four of the most exciting alternatives; from the speed-focused NASCAR to the extreme terrains of the World Rally Championship, this article's for all you petrolheads. Those with their heads in the clouds will love reading about the decoy flares used to confuse heat-seeking missiles and finding out how they work.



61 Mending windscreens



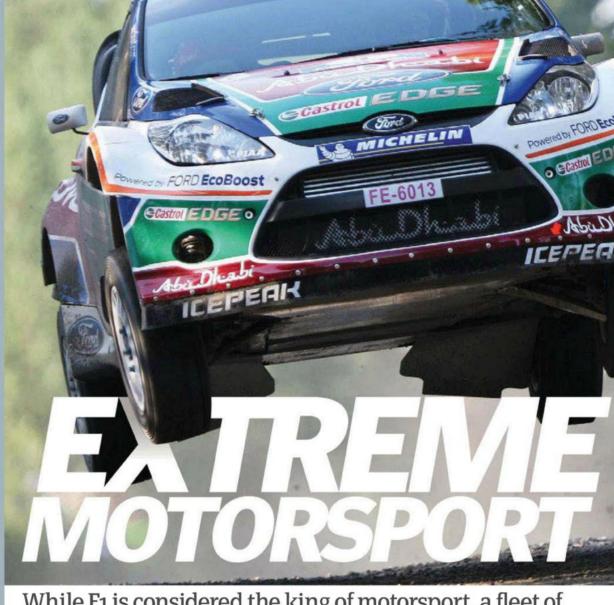
61 Tugboats



61 Chain ferries

TRANSPORT

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- **62** Decoy flares



E STATE OF S

While F1 is considered the king of motorsport, a fleet of other adrenaline-pumping racing series are vying for its crown, offering all manner of high-octane action



Man and machine as one, unbridled by restrictions, whether of the physical, financial or metaphorical variety; in short, racing in its purest form. A free, open and level arena where humans push the

boundaries of conventional physics for glory in a battlefield that demands only the highest levels of skill, engineering prowess and cutting-edge tech. Some would argue that, today, this ideal is only partially delivered by the world's top-tier motorsport – Formula One – insisting that all the greedy conglomerates and human politics have detracted from the thrill of the race.

The motorsport king's corruption will be short-lived however if left unchecked, as surrounding it is a host of youthful, experienced and dynamic contenders, delivering purer racing

in all its forms. From the supreme speeds of NASCAR, through to the extreme endurance delivered by Le Mans, awesome aerodynamics of Formula Two and on to the off-road insanity of the World Rally Championship, racers and racing fans alike are flocking to their banners, tempted by affordable racing thrills, innovative engineering and the diverse tracks.

Over six pages we scout out these maximum-power motorsports, delivering detailed run-downs of how they work, the state-of-the-art hardware, advanced engineering and spectacular racing circuits, in an attempt to tap into their appeal and understand how now, more than ever before, they should be celebrated. So to learn all you need to know about F1's rivals, put the pedal to the metal and let's go!

5 TOP FACTS

Prolific

NASCAR sanctions over 1,500 races across 100 tracks in 39 states throughout the USA and Canada. Additional exhibition races are often held in Japan, Mexico and Australia.

2 The NASCAR Sprint Cup Series is the sport's most prestigious tier of racing and, as a result, is often referred to as NASCAR by fans, ignoring the Nationwide Series among others.

Trucks

3 Interestingly, NASCAR runs the Camping World Truck Series, a contest where racers drive modified pickup trucks. The most recent champion was American Austin Dillon.

Money

A NASCAR is broadcast in over 150 countries worldwide and has an estimated fan base of 75 million. Each year NASCAR makes over \$3 billion from licensed product sales.

5 In 2007 NASCAR switched to unleaded fuels for all of its top series amid criticism of excess pollution. In 2011 it began using E15 'green' fuel (15 per cent ethanol and 85 per cent gasoline).

DTD YOU KNOW? The NASCAR Sprint Cup Series trophy was designed by Tiffany & Co and is made of solid silver



Sprint Cup Series NASCAR

Famed for its insane speed and danger, NASCAR is the second-most-watched motorsport on Earth, delivering frenzied action for racers and fans

Broadcast in over 150 countries, generating \$3 billion a year in revenue and holding 17 out of the top 20 attended single-day sporting events in the world, NASCAR is one of the most popular - and intense - motorsports on the planet. While NASCAR sanctions over 1,500 races a year within multiple series, its top-tier event is the Sprint Cup Series, a ferocious melding of high-powered stockcars (see 'NASCAR teardown' for a hardware breakdown) with America, Mexico and Canada's tightest and fastest race circuits.

The competition works in two segments. Throughout the first 26 races - races are held at various circuits, including the prestigious Daytona International Speedway in Florida - 49 drivers from 22 construction teams vie for a place within the top ten, being awarded points ranging from 43 for first place downwards. At the close of the first 26 races the top ten drivers (as well as a further two wildcards) enter into the second stage of the competition, which is referred to as the 'Chase for the Sprint Cup'. From here the 12 drivers have the points equalised to a level playing field once more and then compete over the next ten races for the championship trophy.

Why split the series in two? To make sure maximum racing skill needs to be employed in every race and that the competition is never wrapped up mid-season - something

recently demonstrated in the Formula One 2011 season, where Sebastian Vettel won the F1 Championship over a month and a half before the final race took place. As such, NASCAR delivers







Unlike many other motorsports, NASCAR Sprint Cup Series cars are equipped with a Jerico, top-loader, four-speed manual transmission with H-pattern shift.



The statistics...

Sprint Cup Series NASCAR

Length: 5,283mm (208in) Width: 1,943mm (76in) Wheelbase: 2,794mm (110in) Weight: 1,451kg (3,199lb)

Engine:

5.9l (1.5gal), 700hp, V8 petrol

Transmission: Four-speed manual



rims. Nitrogen is used instead of air to lessen pressure.

Transmission



"Fz offers fans an opportunity to get closer to the ideal of the pure race than ever before"



FIA Formula Two Championship

Despite Formula One's prestige and higher-powered cars, Formula Two is regarded as one of the purest forms of racing in the world, offering drivers the complete package at a significantly reduced cost

Indeed, it's a lot easier for talented drivers to raise £250,000 (\$311,000) to race in F2, compared with up to £2 (\$3.1) million to do so in GP2 (an F1 feeder series).

combined with Yokohama tyres.

The Formula Two season works by pitting a selection of 24 drivers against one another in 16 races on eight of Europe's most famous racing circuits. Circuits for the 2012 season include the legendary Monza racecourse in Italy, prestigious Silverstone in England and terrifying Nürburgring in Germany.

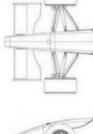
Each course is attacked over a three-day weekend, with drivers hitting the track for a total of 230 minutes. Practice and testing take place on each Friday, with a pair of races following on the Saturday and Sunday. As in Formula One, the top drivers are then attributed championship points – in F2, from 25

for first, down in increments to one point for tenth place. At the end of each season, the points are totted up and ultimately the driver who has accrued the most wins. This earns them not just a trophy, but also a test with the Williams F1 team.

This series is not just the ideal testing ground for ambitious drivers though. Formula Two – largely thanks to the comprehensive all-round package delivered by MotorSport Vision (MSV), the championship's organiser – also offers racing fans an opportunity to get closer to the ideal of the pure race than ever before. Asides from easier financial access to event circuits, Formula Two is broadcast in over 38 countries, into 21 million European homes and for more than 100 hours each season.



Formula Two is, quite possibly, the hottest motorsport in Europe right now, delivering blisteringly fast single-seater vehicles – read: 373 kilonewtons (500 horsepower) and 450 Newton metres (332 pound-force feet) of torque, mindbending physics and some of the most talented drivers outside of F1. Surely, though, it is just a smaller, less-powerful and less-glamorous variant of motorsport's top-tier championship? This is a façade that couldn't be further from the truth. The reason? A completely level and fair playing field for all drivers (see the 'Formula One vs Formula Two' boxout), something granted through a single vehicle constructor, dedicated championship organiser and one of the lowest-cost entry points in the world.



for its brake ducts, nosebox and wings.

Head to Head FORMULA RACING



1. Formula One
The highest tier of singleseater racing sanctioned by
the FIA, FI sees teams and
drivers vie for a single World
Championship. Cars have
upwards of 597kW (800hb).



2. Formula Two
Reborn as the FIA Formula
Two Championship in 2009,
F2 drivers compete in
identical 298kW (400hp)
cars. A high-quality but
low-cost alternative to F1.



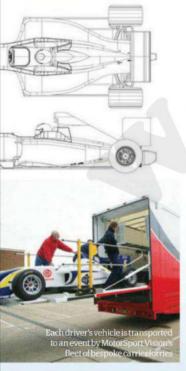
3. Formula Three
A host of series in which
racers – usually younger
drivers aiming to progress to a
higher tier – can demonstrate
and improve their ability. Cars

The Fédération Internationale de l'Automobile's (FIA's) Formula Two Championship was established in 2009

Maximum One of the most exciting aspects of Formula Two from a hardware point of view is each vehicle's Overboost button, which when activated increases the vehicle's engine power from 313 to 373kW (420 to 500hp) for six seconds. The boost feature can be deployed by each car a maximum of ten times during a race, granting the driver extra power for overtaking or to defend a position from a rival. The button is located to the centre-left of the

Brakes
The entire brake system for
Formula Two is supplied by AP
Racing. Both front and rear
master cylinders are aluminium
push-types, brake discs are
made from carbon and grooved,
while pads are carbon metallic.

steering wheel.





Formula One vs Formula Two

F2's profile is growing season by season, challenging F1 with its comprehensive racing package and lower costs

The main reason, excluding differences in hardware, why Formula Two is held in such high esteem by race drivers and fans alike is its low entry costs – allowing junior racers a far greater chance of making it onto the track. All cars are made by Williams F1 identically and all drivers have access to the exact same race engineers, race information (performance statistics and video, etc) and hospitality, which is all co-ordinated and managed by MotorSport Vision. In fact, MotorSport Vision takes its dedication to providing an equal and excellent driver package to such an extent that they even rotate each driver's engineers continually throughout the season, ensuring no driver gets preferential treatment.

This contrasts completely with Formula One, whereby individual teams operate private budgets, vehicles, mechanics, designers, race engineers and hospitality – a fact that leads to a mere handful of drivers realistically being able to compete for the championship each year. It also raises the question: where does driver skill end and car performance/value begin in deciding who takes the Formula One title?



Interview James Goodfield

How It Works speaks to F2's chief engineer about the racing series that's hot on F1's heels

How It Works: Tell us about your role for F2. James Goodfield: I oversee any development undertaken on the F2 car as well as all the engineering over each race weekend. Between events I'm also involved in talking to drivers to make sure that they're happy. At the moment, I am overseeing development work on this year's vehicle ahead of the start of the season, looking at what we can upgrade and basically how we can make the car faster.

I'm also liaising with all of our race engineers to ensure that they have the same information, understand how the new cars are set up and providing a detailed technical manual for their usage. The manual ensures all engineers completely understand how every part of the car works, while a simplified version delivers relevant information to the drivers themselves.

HIW: All F2 cars are built identically by Williams, but is there room for driverspecific tweaks?

JG: Yes. We list on the set-up sheet everything the driver can and cannot change on the vehicle. Many drivers operate the vehicle with just the stock, baseline setup, however others are more dynamic, requesting changes to ride height and tyre pressure, etc.

HIW: You mentioned you were currently looking into potential upgrades for the 2012 season's vehicle – are there any you can discuss?

JG: Last year a lot of the focus was on reliability, as we aim here for 100 per cent reliability

throughout the season. That's always going to be our aim and in 2011 we had a very, very good year; we had a run during the summer of five or six races where we had zero car stoppage issues – which is quite phenomenal at this level. As such, we are in a nice position this year where we can look more at development.

The main thing for 2012 is that we are transitioning to carbon brakes from iron ones. This is exciting as the combined weight of carbon discs and pads will be 12.5 kilograms [27.5 pounds] lighter than the current iron-disc setup, granting the vehicles greater performance.

HIW: You're currently three years in to a five-year tender to run the FIA F2 Championship – what would you say is your goal for the remaining two? JG: There are all sorts of pulls

on us, really. Obviously, reliability is our main goal as we have 24 guys at the start of the season that want to win the championship. If one of them has to stop in a race, especially if they are in a good position, potentially they can lose points that will affect their final result. If no car breaks down, then the result at the end of the year is wholly the result of driver performance.

The other thing we need to achieve in Formula Two – as we are in a competitive environment with Formula Three, GP3 and WSR – is to make sure our performance keeps in step with them. We constantly need to go faster as well as find innovative ways to improve the F2 vehicle.



"Le Mans is a brutal test of driver skill, consistency and concentration"

Beyond Formula One...

Peugeot 908 HDi FAP

We take a look inside one of the most notable Le Mans cars of the post five years to see what makes it a winner



in-house by Peugeot.

The vehicle is powered by an industrial 5.5l (1.5gal) V12 diesel engine, the largest permitted in Le Mans racing. The engine produces 544kW (730hp) and 1,200Nm (885lbfft) of torque. It is twin turbocharged.

Engine

The statistics...



908 HDi FAP LMP1

Length: 4,650mm (183in) Width: 2,000mm (79in) Wheelbase: 2,950mm (116in) Weight: 930kg (2,050lb)

Engine:

5.5l (1.5gal) turbocharged V12 twin-turbo diesel

Transmission: Six-speed seguential manual



once the car crosses the starting line, the driver and navigator are on their own

Wheels

Magnesium-forged, monoblock wheels are supplied by BBS. The wheels are covered with Michelin

24 Hours of Le Mans

The oldest and arguably greatest test of racing endurance, Le Mans demands composure, skill and elite engineering

Think two hours of racing, as undertaken by F1 drivers, is demanding? Well, think again. Le Mans requires drivers to race continuously for 24 hours, with over 50 high-powered racers clocking in over 4,828 kilometres (3,000 miles) over a weekend. It is a brutal test of driver skill, consistency and concentration, with just one mistake liable to, at best, erase hours of excellent driving or, at worst, potentially lead to a fatal accident.

There are four classes to Le Mans: LMP1, LMP2, GTE Pro and GTE Am, which divide vehicles on power, budget and car-type. LMP1 is the most prestigious class, with its custom-built prototypelevel vehicles usually leading each race. While all cars compete at the same time during the race, each class has its own trophy, and despite vast differences in power, it is not unheard of for a lower-tier vehicle to win the overall event as endurance is just as important - if not more so - than power output.

Speed, however, obviously plays an essential role in Le Mans - with drivers rarely dropping below 161 kilometres (100 miles) per hour - and as such, it is not only considered the most gruelling of motorsports but also one of the most dangerous. Since the competition's conception in 1923, 21 drivers have died on the Circuit de la Sarthe (one of the world's longest). There have been numerous high-speed accidents - the most recent being in last year's race, with two Audi-designed LMP1-class vehicles spectacularly colliding at over 274 kilometres (170 miles) per hour.

Brakes

Both front and rear wheels are supported by carbon-fibre ceramic disc brakes, allowing for superb stopping speeds.



Watch professional rally driver Ken Block go flat out on snow and ice

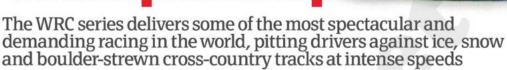


DID YOU KNOW? The average World Rolly Championship car accelerates from o-6omph in just three seconds



Transmission It uses a six-speed sequential manual transmission, combined with an electro-pneumatic controlled gearbox positioned lengthways and with a maximum of six gear ratios.

World Rally Championship



From the desert scrubland of Jordan, through the alpine forests of Sweden and on to the snow and ice of Finland, World Rally Championship (WRC) drivers must take on some of the most demanding and technically challenging terrains in all of motorsport. It's a sport where £650,000 (\$1-million) vehicles are pitted against 13 of the toughest courses in the world and where drivers need to constantly adjust race after race to remain at the front of the pack. As such, the WRC is broadcast in over 180 countries and has a worldwide audience of more than 800 million.

The WRC works by splitting each course into between 15 and 25 special stages, which are short (2.4-kilometre/1.3mile) to long (50-kilometre/31-mile) stretches of closed roads that the driver-along with a navigator-attempt to complete in the shortest possible time.

Each vehicle, when driving to and from each special stage does so on public roads, adhering to regular traffic regulations. The special stages are often tailored to test specific aspects of a driver's skill and vehicle's prowess, ranging from steep downhill sprints, through tight, winding mountain roads and on to rough off-road canyons and scrubland. The racing goes on over a three-day period, with reconnaissance and 'shakedown' testing runs taking place on the first day.

Ford Fiesta K

The anatomy of one of the World Rally Championship's most advanced cars laid bare

A unitary construction bodyshell with unique composite side panels and aerodynamic rear wing grant the RS WRC a light and streamlined chassis. A welded T45 rollcage is installed for driver safety and extra rigidity.

Interestingly - and perhaps another reason why the World Rally Championship has such a substantial fan base - is that as soon as vehicles leave any course's starting point, the driver and navigator can receive no support from the rest of their team; they have to deal with any breakdowns solely by themselves. This adds an extra dimension to each race, with teams racing around and against the clock to get back on the road.



Engine

ARTINI

Ford's 1.6l (0.4gal) EcoBoost engine, in partnership with a high-powered Garrett turbocharger, delivers a restricted (by regulation) 224kW (300hp). The engine is managed by a Cosworth-designed electronic system.

Width: 1.820mm (72in)

Wheelbase: 2,480mm (98in)

Weight: 1,200kg (2,646lb)

Engine:

1.6l (0.4gal), four-cylinder, 16-valve turbocharged Ford EcoBoost engine

Transmission: Six-speed seguential manual

Transmission

A four-wheel drive transmission contains a front and rear differential with clutch disconnect system. A six-speed gearbox is operated by a mechanical shift and using a twin-disc clutch.

Brembo ventilated brake discs with four-piston monoblock callipers deliver insane stopping power across all surfaces. The brakes can be adjusted to provide either a front or rear bias.



The Fiesta RS can be equipped with either 20 x 46cm (8 x 18in) wheels for asphalt surfaces or 18 x 38cm (7x15in) aluminium wheels for gravel and snow. All tyres are from Michelin.

Brakes

Is your photography missing something?









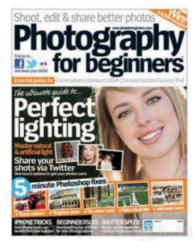


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Head to Head THE ULTIMATE TUG OF WAR



1. Horse
Originally horsepower
was designed to compare
the power of draught
horses and steam
engines. One horsepower
equals about 736 watts.



2. TA300
The TA300 articulated dump truck has a 287-kilowatt (385-horsepower) engine and can carry up to a 30-ton load



3. The Edward J Moran

One of a very powerful series of tugboats, with a 4,848-kilowatt (6,500-horsepower) twin engine, it can haul up to 94,000-ton vessels.

DID YOU KNOW? 40mm windscreen cracks can be repaired, but in the 'A- zone' in front of the driver, only 10mm faults can be fixed



Chain ferry platforms The mechanisms guiding cable ferries

There are three primary types of cable ferry: reaction ferries, handoperated ferries and powered-chain ferries. Reaction ferries use the power

of the river itself to 'tack' across the current while the other two both operate off the same basic apparatus of powered cogs or drums. These run along either side of the ferry and act as guides for the chains, drawing them in and around their circumference before letting them fall back to the riverbed or seabed.

The chains themselves have a tremendous amount of slack built in to protect other boats. Otherwise, instead of sinking back to the bed of the channel/river once the ferry has passed by, the chains would remain on the water's surface, or just beneath, where they could cause serious damage to other vessels.



Cracking repair jobs The secret to fixing cracked windscreens



The vast majority of modern car windscreens are constructed of two layers of laminated safety glass and often have a layer of plastic laminate between them. As a result, repairing small cracks is a relatively easy operation as they tend to only affect the outer layer of glass.

Repairing cracks involves using a drill to break through the damaged glass and get down to the lamination layer. Once the drill has reached the lamination layer the next step is to inject an adhesive resin. This resin is often based on polyurethane, a polymer that's flexible like rubber but at the same time retains rigidity like plastic, which is ideal for fitting into the already-established shape of the windscreen. Once in place, the resin is cured with ultraviolet light, causing it to harden. This not only seals the crack but in a lot of cases reduces the prominence of the crack, restoring near-complete visibility as well as much of the windscreen's original strength.



Tugboat power explained

Discover why the smallest ships are also often the strongest



Kort nozzle

One of several types of tug propulsion, Kort nozzles focus

the thrust of the propeller.

Tugboats have a 507-2,535-kilowatt (680-3,400-horsepower) engine, which can grant them a power-to-weight ratio of up to 4.50. This is a measure of the sheer brute force of an engine, worked out by dividing the engine's power by the

Propulsion

Tug propellers can rotate up

to 360 degrees, allowing the tug to manoeuvre easily.

weight of the vehicle. It's also a mark of how extraordinarily strong tugboats are, relative to their size, given that the power-to-weight ratio of the much bigger ships they tow varies between 0.30 and 1.20.

The key to a tugboat's success lies in how it utilises this strength. Z-drive propellers are designed to rotate 360 degrees so that the tug can change direction on the spot. Similarly, the Voith Schneider Propeller (VSP) system often employed uses a series of blades whose angle can be altered so they can provide thrust in any direction, once again allowing the tug to haul or push its charge into any position.



"There are two main types of countermeasure flare – pyrophoric and pyrotechnic"

The CH-46 Sea Knight is designed to provide all-weather, 24-hour assault transport for US Marine Corps combat troops. As such, it is equipped with a wide variety of countermeasure devices

Decoy flares

One of the most widely used aerial countermeasures in the world, decoy flares offer a simple but robust last line of defence against incoming missiles



Decoy flares, as commonly used by military aircraft, work by generating a heat signature in excess of the launch vehicle's jet engines. This has the effect

of confusing any incoming heat-seeking missile's homing system into locking on to the flares' signatures instead of the aircraft's, causing it to explode at a safe distance and saving the pilot's life.

There are two main types of countermeasure flare – pyrophoric and pyrotechnic. The former is

activated automatically on contact with air and the latter by the mechanical removal of a friction cap prior to firing. Pyrotechnic flares use slow-burning fuel-oxydiser mixtures to generate heat, such as MTV (magnesium/Teflon/Viton), while pyrophoric variants use either ultra-fine, aluminium-coated iron platelets or liquid compounds such as triethylaluminium. The composition of either type of flare is often tailored to counter specific missile systems or to mimic the launch jet's heat signature.

All military aircraft being built today are fitted with automatic flare dispensing systems, which actively track incoming missiles and launch flares accordingly at optimal range to avert damage, while older or civilian aircraft usually require the pilot to activate the flare launches manually. Systems are fairly flexible and flares can be dispensed one at a time, over long or short intervals and even, if desired, in large clusters – as demonstrated by the CH-46E Sea Knight in this stunning image.

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DID YOU KNOW? Modern military aircraft launch flares automatically when missiles are detected in close proximity













When stars go large



This month in Space

section this issue, bask in the glory of this spectacular artist's interpretation of Betelgeuse, one of the Betelgeuse, one of the closest supergiant stars to Earth. Next we find out exactly how the Magellanic Clouds were pulled into the Local Group of galaxies of which we are a part before looking at the next generation of space stations that are inflatable – anyone got a foot pump? Finish with a roundup of Finish with a roundup of Russia's Venera missions to Venus, which broke lots of new ground in their day.



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68 Inflatable space stations



70 Venera probes

SPACE

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- 67 Solar tsunamis
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- 70 Venera probes

Supergiant stars

We take a look at the biggest stellar bodies in the universe



Put the Sun next to a supergiant star and you'll have a hard time finding it. Supergiant stars, as the name suggests, are the largest kind in the universe.

They can be thousands of times bigger than our Sun and have a mass up to 100 times greater. The largest-known supergiant star, VY Canis Majoris, is up to 2,100 times the size of the Sun (based on upper estimates). If it were put in the position of our Sun, it would extend out to the orbit of Saturn.

Supergiants come in a variety of sizes and temperatures, but they are typically classed as being either red or blue. Red supergiants have a mass of at least eight solar masses and are generally old stars that were once similar in size to the Sun. They form when a star more than ten times the mass of our Sun runs out of hydrogen fuel in its core, preventing any further fusion.

It subsequently starts to collapse but, as it does so, the hydrogen in its outer shells begins its own process of fusion. At this point the entire star experiences fusion and begins to burn through the rest of its fuel supply at an astounding rate. In fact, they can burn all of their remaining hydrogen in just a few million years, compared to the severalbillion-year lifetime of stars like our Sun. During this period they will shine at least 100,000 times brighter than our galaxy's star. At the end of their life, red supergiant stars often explode as a supernova, producing either a neutron star or a black hole as a result. The nearby red supergiant Betelgeuse, which is around 1,000 times the mass of the Sun, is only 8.5 million years old but is expected to go supernova within the next millennium.

Blue supergiants are considerably hotter than red supergiants, but generally much smaller-only about 25 times the size of the Sun. Like red supergiants they have very short lifetimes of only a few million years. They usually form when a star more than ten times the mass of the Sun heading towards its own demise enters a slow-burning phase. However, red supergiants can also turn blue if their own rate of nuclear fusion begins to decline; in fact, a star can continually switch between red and blue supergiant over the course of its life. Between the two extremes it can also become a yellow supergiant, such as the North Star (Polaris). However, stars of this nature tend to spend the majority of their existence as red supergiants rather than in their blue or yellow forms. •



Betelgeuse, shown here, is a supergiant star 640 light years from Earth in the Orion constellation. It has 20 times the mass of the Sun.

Head to Head



1. Betelgeuse This star, which is located in the Orion constellation (his shoulder), is 10,000 times more luminous tha the Sun and about 370



2. Eta Carinae this star is about 400 times the size of our Sun but due to its scale it loses a large amount of its mass every year.



3. VY Canis **Majoris** his star 5,000 light years from Earth is up to 2,100 times the size of the Sun. It takes light over eight hours to

DID YOU KNOW? Supergiant stors larger than 100 solar masses are sometimes referred to as hypergiants

Rigel Orbit Type: Blue supergiant If Betelgeuse were placed at the How big is a supergiant? Mass: 24 solar masses centre of our solar system, it would reach beyond the orbit of Mars and Size: 71 solar radii Temperature: 12,130K possibly even out to Jupiter. (11,860°C/21,380°F) Distance from Earth: Supergiant stars dwarf all 860 lightyears others in the cosmos. Here's a look at how the various types stack up **Antares** Type: Red supergiant Mass: 12.4 solar masses Size: 883 solar radii Temperature: 3,400K (3,130°C/5,660°F) Distance from Earth: 550 lightyears Sirius A Sun Type: Yellow dwarf Type: White star Mass: 2.02 solar masses Mass: 1 solar mass Size: 1.711 solar radii Size:1solar radius Temperature: 5,778K Temperature: 9,940K (9,670°C/17,430°F) (5,500°C/9,940°F) Distance from Earth: Distance from Earth: 8.6 light years o.oooo16 light years Core The dense core of a red ergiant contains layers avy elements, ranging on at the very centre rogen at the edges. Inside a red supergiant Exterior The outer layer of a red supergiant is blown off when Interior and the star goes supernova. This Around the core is an area consisting of a substantial amount of hydrogen and other are key to forming new planets. elements which may undergo fusion. What's the lim The colder a supergiant star, the larger it can become. Currently the biggest star we know of is VY Canis Majoris, at 2,100 times the size of the Sun. Canis has a temperature of 3,500 Kelvin (3,227 degrees Celsius/5,840 degrees Fahrenheit). Estimates suggest a supergiant star at 3,000 Kelvin (2,727 degrees Celsius/4,940 degrees

Fahrenheit) would be 2,600 times the size of our Sun; this is believed to be the upper limit before a star collapses in on itself.



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DIDYOUKNOW? When solar tsunamis were first observed, scientists thought they were merely the shadows of solar flares

Inside the Magellanic Clouds

Where did these galaxies come from?

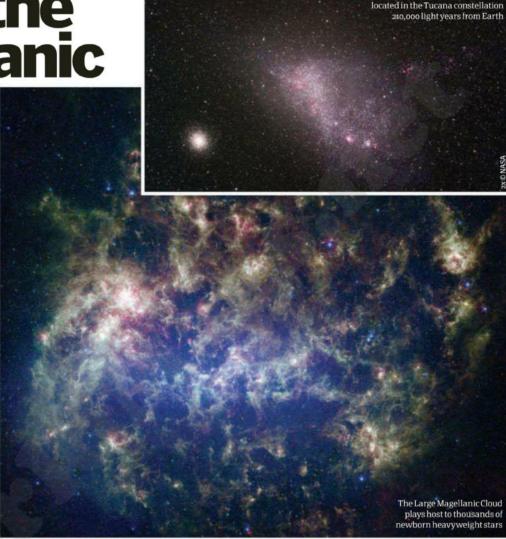


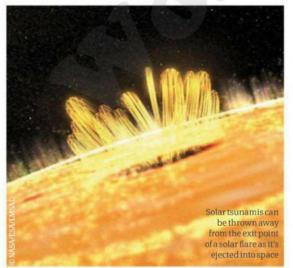
The Magellanic Clouds consist of two irregular dwarf galaxies, both of which are found in the Local Group of galaxies that

includes our own Milky Way.

The Large Magellanic Cloud (LMC) is the biggest of several galaxies in our vicinity, spanning 30,000 light years across and located 160,000 light years from us. It's packed full of young star-forming nebulas and is home to mainly blue-white hot stars. The Small Magellanic Cloud (SMC) is somewhat more miniature, measuring in at 15,000 light years wide, and is 210,000 light years from us. The SMC has a mass around 7 billion times that of our Sun.

Perhaps the most interesting thing about the two galaxies is their origin. Both of them are moving rapidly – roughly equal to the velocity needed to escape from the Milky Way, suggesting that rather than forming in our own galaxy as was first thought, they were 'snared' by the Milky Way as they travelled past. Their movement and speed suggest that they were thrown out of the nearby Andromeda galaxy no more than 8 billion years ago, hurtling through space before entering the orbit of the Milky Way.





Solar tsunamis

The mega-waves of energy that tear across the Sun



Solar tsunamis, also known as Moreton waves or fast-mode magnetohydrodynamic (MHD) waves, are surges of material sent

crashing across the Sun as the result of a solar flare being launched into space. They can travel up to an incredible 1.6 million kilometres (1 million miles) per hour.

Solar tsunamis are made of hot plasma and magnetic energy. The first was observed by Gail Moreton in 1959, and since then several more studies have been conducted on the phenomenon by the Solar and Heliospheric Observatory (SOHO) and the Solar Terrestrial Relations Observatory (STEREO) spacecraft.

The tsunamis are formed when the Sun emits a coronal mass ejection (CME), a massive burst of solar wind commonly associated with solar flares. Around the ejection point a circular wave extends outwards in all directions travelling at a super-fast rate.

The Small Magellanic Cloud is

In February 2009, the two STEREO spacecraft watched as a billion-ton cloud of gas was hurled off the surface of the Sun from a CME. The result was a solar tsunami that towered 100,000 kilometres (60,000 miles) high speeding across the star's surface at about 900,000 kilometres (560,000 miles) per hour. Estimates indicate it contained the same energy as 2.4 million megatons of TNT.



"Kevlar fabric modules were more resilient to micrometeoroid impacts than the casings of the ISS modules"

Blow-up space modules



Inflatable space stations

Could this new type of module revolutionise space living?

Inflatable space modules are a proposed way to set up sizable space habitats in Earth orbit at a much lower cost than currently possible. Unlike the existing modules on the International Space Station (ISS), which must be constructed and launched in their finished state, inflatable modules would be folded up on the rocket. Once they reach orbit they would be pumped full of a gas, such as nitrogen, to expand to their full size. It is estimated that just one inflatable module packed into a rocket could one day have the potential to expand to the size of the entire ISS, roughly equivalent to an American football field, which is about 100 metres (328 feet) in width.

At the forefront of inflatable space technology is Bigelow Aerospace. This company has launched and tested two modules in space - Genesis I and II (in 2006 and 2007, respectively) - which have proved that inflatable modules are just as reliable, if not more so, than their metallic counterparts. In one test, Bigelow found that its Kevlar fabric modules were more $resilient to \, micrometeoroid \, impacts \, than \, the \, casings \, of \, the \, ISS \, modules. \, Bigelow's \, next$ inflatable spacecraft will be the Sundancer module, due to launch by 2014 at the earliest. It will be the first inflatable module in orbit around Earth capable of supporting humans on board. 🌣

Docking The inflatable shell, which is 30cm At the top of the module is an (one foot) thick, is made of multiple airlock, allowing it to be layers to provide insulation and attached to other similar protection from orbiting debris. modules or even to other space stations like the ISS. Shape Superstrong woven Kevlar is used on the interior of the shell to ensure the module keeps its shape when it is inflated. Structure

The spacious interior is about 8.2m (27 feet) in diameter and can house different areas including exercise

Most of the external shell is made of a material called Nextel, an insulating material found under the hoods of cars, placed between sheets of foam.

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DID YOU KNOW? NASA has looked into filling stations, or propellant depots, orbiting Earth for rockets on deep-space missions

Rocket fuel

How does this powerful propellant take spacecraft into the cosmos?



Rocket fuel works on the basis of Newton's Third Law of Motion, which states that 'every action is accompanied

by an equal and opposite reaction'. By firing fuel out the back of a rocket, the force propels it upwards with acceleration equal to the force at which the fuel is expelled. It is almost identical to how a jet plane is able to fly in the atmosphere. However, one difference is that jet planes use oxygen in the atmosphere to ignite their fuel, while a rocket must carry its own oxidiser.

There are two main types of rocket fuel used on modern rockets: liquid and solid. Liquid propellants separate fuel and oxidisers and the two are combined in a combustion chamber where they burn and are fired out from the base of the rocket. While more complex than solid fuel, the ability to control the flow of propellant means the engine can be throttled to a particular speed. Liquid fuels are further

subcategorised into either petroleum, cryogens or hypergols. Petroleum is fuel derived from crude oil and hydrocarbons, cryogens are those stored at very low temperatures (such as liquid hydrogen), while hypergols are able to self-ignite on contact between the fuel and the oxidiser.

Solid rocket fuels are those in which the fuel and oxidiser compounds are already combined. Most use an aluminium powder as the fuel and an ammonium perchlorate as the oxidiser, while an iron powder is used as a catalyst for the reaction. All that's required is a spark to start them burning. While they are much simpler than their liquid counterparts, they cannot be stopped once they have been ignited. For that reason, solid fuels are generally used more for the initial launch sequence, when the speed needs to be at its maximum, whereas liquid fuels are used later so the speed can be adjusted to get the rocket's payload on to the right trajectory.



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"Despite many technical hitches, the Venera spacecraft are regarded as a success"

Venera probes

The highs and the lows of these groundbreaking Russian missions to Venus

Venera 10 returned this image from Venus on 25 October 1975 during its 65 minutes of operation





The Venera probes were a series of spacecraft designed by the USSR to glean unprecedented data on the hottest planet in our solar system: Venus.

Venera 1 was the first to launch in 1961, followed by 15 more missions through to 1984. The spacecraft encountered numerous problems and glitches in almost every launch, but there was more than enough data returned to label the overall mission a success. The spacecraft were launched in batches across the 23-year period, with each group possessing new and upgraded features based on the experiences from the previous missions.

The first two spacecraft – Venera 1 and 2 – were designed as spherical probes intended to merely perform a flyby of the planet and provide information about the density of its atmosphere and temperature. Unfortunately, both probes suffered a communications failure after leaving Earth orbit so

couldn't send any data back, although Venera 1 is thought to have come within 100,000 kilometres (62,137 miles) of Venus, thus becoming the first manmade object to pass the planet.

The next four spacecraft – Venera 3 to 6 – employed a similar spherical design but were somewhat heavier, weighing about a ton. Although Venera 3 was unsuccessful, earning itself the unwanted accolade of becoming the first spacecraft to crash-land on another planet on 1 March 1966, Venera 4 finally returned positive results and became the first spacecraft in history to measure the atmosphere of another planet. Each of the spacecraft carried a probe to attempt an atmospheric entry, but the Soviets grossly underestimated Venus's surface pressure, believing it to be just 25 times more than Earth's when in fact it is closer to 100 times, and thus the first two probes were instantly destroyed once they entered the atmosphere. Realising their design

error, the USSR's space agency decided to jettison the majority of the instruments on Venera 5 and 6 mid-flight and instead use them solely as atmospheric entry probes; each managed to survive for over 50 minutes in the harsh atmosphere.

The remaining missions were designed to land and operate on the surface of Venus, taking into account the intense pressure measured in previous missions. Venera 7 was the first spacecraft in the programme specifically tailored to survive the intense pressure and heat on Venus's surface (see the 'Landing on Venus' boxout for more detail). It became the first spacecraft to transmit data from the surface of Venus on 15 December 1970 despite a



1. Venera 3
This Russian probe was the first spacecraft to impact another planet - Venus - in 1966. Due to equipment damage, no

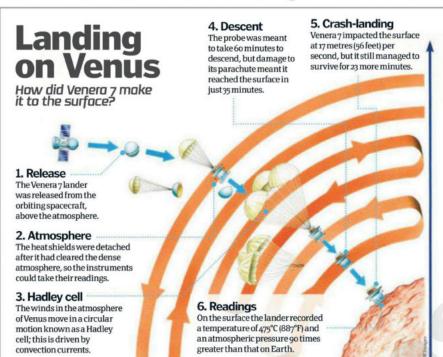


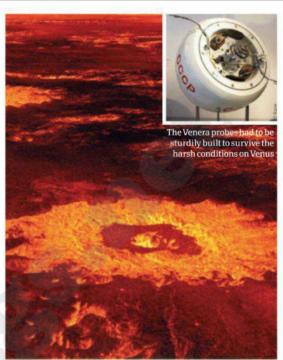
2. Mars 2
This Soviet-built unmanned probe, with a fairly unoriginal name, crash-landed on Mars in 1971, becoming the first spacecraft to 'touch down' on the Red Planet.



3. Huygens
On 14 January 2005 the
Huygens probe performed
the first and only landing in
the outer solar system,
successfully touching down
on Saturity group Titan

DID YOU KNOW? Russia and the USA are the only two countries to successfully land spacecraft on another planet



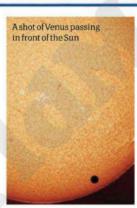


parachute failure shortly before landing, which saw it impact the surface at almost 65 kilometres (40 miles) per hour. It survived for 23 minutes, as planned, and despite possessing very few experiments, it was still able to return information on the temperature and pressure, which were calculated at 475 degrees Celsius (887 degrees Fahrenheit) and 90 atmospheres (190,460 pounds per square foot), respectively. Venera 8 was nearly identical to Venera 7 save for a few additional instruments, and it was able to survive on the surface for almost an hour.

Venera 9 to 12 were much larger than their predecessors, weighing close to five tons. They included an orbital craft that relayed data from each spacecraft's landing probe, designed to operate for 30 minutes. For the first time each lander also included two cameras, but unfortunately all of the landers suffered a camera malfunction. Venera 9 and 10 lasted about an hour on the surface and managed to return some images, with the former becoming the first to do so from another planet, but the camera lenses on both Venera 11 and 12 failed.

Venera 13 through to 16 were similar in design but contained more instruments including a drill, compressibility arm (to determine the rigidity of Venus's surface) and a seismometer. They both returned images and data from the planet, but unfortunately for Venera 14 its lens cap was ejected directly beneath its compressibility arm, so it was unable to analyse the surface.

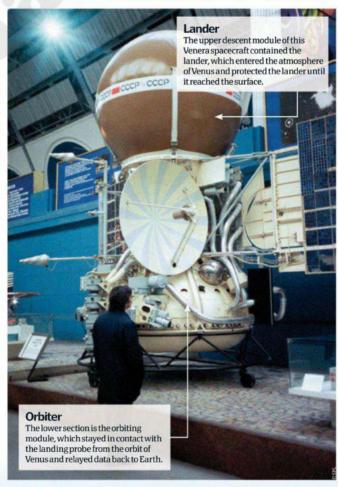
Despite their many technical hitches, the Venera spacecraft are generally regarded as a success for the Soviet space programme, providing a substantial amount of data on Venus. They paved the way for the two Russian Vega spacecraft in 1985, which released atmospheric balloons on Venus that stayed active for two days.



VENERA LAUNCHES

A roundup of when all the Veneras took off...

Venera 1: 12 Feb 1961 Venera 2: 12 Nov 1965 Venera 3: 16 Nov 1965 Venera 4: 12 June 1967 Venera 5: 5 Jan 1969 Venera 6: 10 Jan 1969 Venera 6: 10 Jan 1969 Venera 8: 27 Mar 1972 Venera 9: 8 June 1975 Venera 10: 14 June 1975 Venera 11: 9 Sept 1978 Venera 12: 14 Sept 1978 Venera 13: 30 Oct 1981 Venera 14: 14 Nov 1981 Venera 15: 2 June 1983



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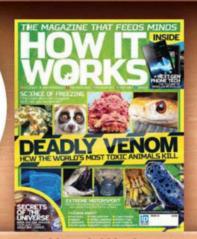
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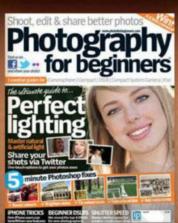
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A record-breaking submersible

This month in History

This month we are diving straight into history, with an in-depth look at one of the most time - the Bathyscaphe Trieste.
This two-manned vessel broke
a record for travelling to the
deepest known area in Earth's
oceans - the Challenger Deep near Guam – back in 1960 and it retains its title to this day. Another watery marvel explored is how the City of Canals was built over a lagoon, while firmly on dry land we consider how thatchers have gone about their craft for centuries. Also revealed are the inner workings of







78 Venice deconstructed

HISTORY

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78 How Venice was built

Bathyscaphe Trieste Could largely only move up and down on a vertical

A real-life Nautilus, the Bathyscaphe Trieste explored the deepest parts of Earth's oceans, remaining to this day the only manned vehicle to have reached the bottom of the Mariana Trench in the Pacific



After passing 9,000 metres (30,000 feet), one of the Plexiglas windows cracked. Over 1,000 atmospheres - a

pressure over six tons per square inch - relentlessly bore down upon the Bathyscaphe Trieste. The hull shook violently, threatening to collapse under the mighty strain. If fractured on even a microscopic scale, the weight of the Earth's deepest ocean would rip the vessel in two, triggering explosive decompression and instantly killing both oceanographer Jacques Piccard and pilot Lieutenant Don Walsh of the US Navy. 23 January 1960, however, was not their day to die. The men had still not reached the bottom of the Mariana Trench's Challenger Deep; the structure had to hold - there was no plan B.

Descending further into the black void, completely cut off from the outside world-the sonar/hydrophone communications system had packed up hours ago - the Trieste continued to dump iron pellets into its ballast system. After all, you don't descend vertically nine kilometres (nearly six miles) beneath the surface of the ocean only to quit so close to your goal. Then finally, out of nowhere and after four hours and 48 minutes within a two-metre (seven-foot) pressurised sphere, Piccard, Walsh and the Trieste touched down. Clouds of diatomaceous ooze (made of the skeletons of dead sea-creatures) diffused from the seabed on contact. filling the surrounding water with a liquidated organic haze.

Half an hour later, after periodically observing this alien environment with high-powered quartz arc-light lamps -

periodically as when activated they caused the water to violently boil - and discovering a multitude of life including a white flatfish, several shrimp and jellyfish, Piccard initiated the Trieste's ascent. The vessel had held, but at a depth of 10,916 metres (35,814 feet) the temperature of the pressure sphere was dropping continuously (the minimum recorded was just seven degrees Celsius/45 degrees Fahrenheit); if they were not careful, there would be no return. Three hours and 15 minutes later, the Trieste re-emerged into the daylight and human civilisation. The vessel and its crew had been to a world only envisioned in fiction and returned with field-changing information.

Key to the data gathered was establishing the existence of life at the bottom of Earth's deepest ocean. This revealed that not only were there creatures impervious to extreme atmospheric pressures, but also that water at this depth wasn't stagnant. This was a clear indication that ocean currents even penetrated these extreme depths, so they should not be used as a dumping ground for radioactive waste. Unfortunately, despite this first-hand evidence, dumping of this kind still continues throughout large parts of the world to this day.

Today the legacy of the Trieste is being built upon, with numerous programmes currently underway focused on designing new vehicles to return to this uncharted territory. The most high profile of these is Richard Branson's Virgin Oceanic, which intends to return to the bottom of the Mariana Trench in the latter part of this year.

move up and down on a vertical plane. However, small, top-mounted propellers allowed a little horizontal movement.

Water tanks

At fore and aft of the hull lay twin water-filled ballast tanks.



Quartz lamp

High-powered quartz arc-light lamps enabled the Trieste's crew to observe their immediate environment. These were mounted to the bottom of the hull.

A close-up view of the Trieste's pressure sphere, clearly showing the Plexiglas observation window and instrument leads



Launch

1 The Trieste was launched on 26 August 1953 into the Mediterranean Sea near Capri. It proceeded to operate in the vicinity for five years under the command of the French Navy.

Purchase

2 In 1958 the Trieste was bought by the US Navy. It was used in Project Nekton, a series of dives in the Pacific Ocean near Guam, where it first entered the Challenger Deep.

Sphere

3 During the USA's ownership the Trieste was fitted with a new pressure sphere. This was produced by Krupp Steel Works of Essen, Germany, and weighed in at 13 tons.

Robots

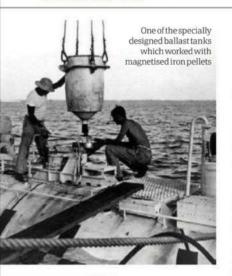
4 No other manned vessel has returned from the Challenger Deep. In 1995 a Japanese robotic craft reached the bottom, as did a remotely operated vehicle in 2009.

Retirement

5 In 1980 the Trieste, which had been continuously redesigned for three decades, was retired and taken to the Washington Navy Yard. It's now housed in the US Navy's museum.

DIDYOUKNOW? The Trieste was designed by Swiss scientist Auguste Piccard – the father of Jacques who co-piloted it

TRIESTE



Inside the Bathyscaphe Trieste

How It Works takes a look at the machinery and technology that enabled this record-breaking dive

Electromagnets

The magnetic iron pellets that allowed the Trieste to descend so deep were held in place actively by large electromagnets. As such, if there was an electrical failure, the vessel would automatically begin to rise.



The Bathyscaphe Trieste is now **Entrance tunnel** exhibited at the National Museum of

The pressure sphere was accessed from the deck of the vessel by a narrow vertical shaft that penetrated the float.

Hull

The Trieste's hull was made from steel and held numerous ballast tanks. The pressure sphere that contained the vessel's crew was mounted centrally to its belly.

the US Navy in Washington DC



operation, the sphere was constructed from 13cm (5in)-thick steel and housed the crew and the vessel's instrumentation.

Observation window

The only transparent material on the entire craft, the observation window was made from a cone-shaped block of shatterproof Plexiglas (acrylic glass).

Pellet tanks

Magnetised iron pellets were contained within special ballast tanks to enable a fast and deep dive. These were held in an active state by electromagnets.

Gasoline tanks

Due to the extreme weight of the pressure sphere, large gasoline-filled tanks were used to ensure neutral buoyancy. Gasoline was chosen as it is relatively incompressible at extreme pressures.





Bathyscaphe Trieste

Type: Bathyscaphe

Crew: 2

Displacement: 51 tons

Length: 18.1m (59.6ft) Beam: 3.5m (11.6ft)

Draft: 5.6m (18.6ft)



"One of the best modern-day examples of gun turrets can be seen on battleships"

Gun mounts / Fountain pens



These armoured structures can soak up hefty damage while dealing out awesome firepower



A gun turret works by protecting the crew or computer mechanism of a projectile firing weapon,

allowing it to operate with greatest freedom and safety. Gun turrets are often mounted on fortified buildings – such as anti-naval land batteries – or on military-grade vehicles such as APCs and aircraft carriers.

The turret itself can house a wide variety of armaments, often consisting of machine guns, automatic cannons, large-calibre guns or missile launchers, and is either controlled manually by its human crew or remotely by computer systems. One of the best modern-day examples of gun turrets can be seen on battleships, which have the largest cannons and the most sophisticated loading mechanisms.



Armoured gun house
The part of the turret that
features its weaponry. This
is the most exposed and
therefore heavily armoured
section of the structure.

Powder hoist
The element
dedicated to lifting
and loading the
explosive substance
into the cannon.

The ammunition of choice often large-scale explosive shells – is hauled up from the projectile handling floor by this lift mechanism.



Supporting the turret's cannons, the lug enables the guns to be incrementally adjusted depending on the range of the target.

Roller path

The roller path dictates the degree of rotation possible by the gun house.

Barbette

The barbette is a protective circular armour that surrounds the lower turret.

Magazine --

An area dedicated to ammunition storage.

Turret foundation

turret that provides it with a

and absorb its blast shocks.

platform from which to rotate

This is the stationary part of the



A gun this size is mostly automatic, however crew-members are still required in most cases to transfer the ammunition from the magazine to the projectile hoist manually.

Machinery floor This is where the majority of

his is where the majority of the turret's mechanical machinery is located.

Powder handling floor

As with the projectile floor, the explosive substance used to propel the missiles must be manually loaded and this occurs here.

How do fountain pens work?

Considered the king of all writing instruments, this pen has a complex design and structure



Fountain pens work, in general, by transporting ink from a sealed container (usually a cartridge) through a

hole, into a finned feed and down to the tip of the nib. As the nib comes into contact with a surface, such as a sheet of paper, the ink is drawn out of the nib through capillary action, causing more ink to be drawn through the feed from the sealed container. Importantly, as the container is sealed, a vacuum is created within as the ink is removed and this – in partnership with the ink's surface tension as well as its molecular attraction to the pen's metal nib – causes it to flow in a controlled and consistent way. It also means the ink ceases to flow when the nib is lifted.



How It Works breaks down a typical fountain pen to see how it writes with such finesse

Nib

The point of contact for the pen, the nib narrowly distributes ink onto a writing medium like paper. Nibs are commonly made from gold plate to avoid corrosion.

Cap

A protective cover for the delicate pen nib, the cap is often installed with a clip for easier portability.

Feed

Arguably the most important part of the pen, the feed controls the flow of ink out of the reservoir and distribution to the nib. The feed on a modern pen is commonly made from hard rubber or vulcanite.

The casing for the internal

components, the barrel tends to be made from plastic or lightweight metals. It is often tapered for ergonomic purposes.

Reservoir

A sealed container, such as a cartridge, that holds the pen's ink. Ink is drawn from the reservoir into the feed for controlled distribution.

Section

The lynchpin of the pen, the section holds together all of the various parts within the barrel and cap, including the feed, breather tube and nib.

5 TOP FACTS THATCHING TRIVIA

Guidebook

To this day the thatchers' bible is considered to be *The Thatcher's Craft* (1960) that details the complete history of the trade, as well as building techniques and tools.

Premium

2 Due to their flammable materials, thatched roofs lead to a significantly higher insurance premium; the rate is higher still if the house has a working chimney.

Rose

3 Shakespeare's Rose Theatre was burnt to the ground due to its thatched roof. A burning wad of cloth ejected from a special-effects cannon is believed to have started the blaze.

Life span

Different thatching materials have varying life spans; water reed lasts 40-60 years, wheat reed 25-40 years, long straw 20-35 years and a new ridge (a top-up straw layer) 10-15 years.

Pitch

Not all roofs can be thatched. In order to thatch a roof it must have a pitch no less than 45 degrees, as otherwise rainwater can backwards penetrate the material and quickly ruin it.

DIDYOUKNOW? On average, 93 square metres (1,000 square feet) of roof space takes three to five weeks to thatch



Thatching explained

This traditional – and now very pricey – craft requires a host of speciality tools and techniques



Thatching is the craft of building a roof with a variety of dry vegetation, ranging from wheat and water reed through to long straw and heather.

The basic principle is to layer the thatch material in such a way that rainwater is shed away from the inner roof and off the side of the building, providing a waterproof barrier much the same as that granted by typical slate/tile-based roofs.

Any thatching operation starts with the preparation of the thatching material, with straws/reeds bundled together into a loose sheaf. The sheaf is then levelled off by first knocking it against the ground to force all strands to descend to the bottom, then secondly removing any remaining anomalies, and finally shearing off the bottom inch. This last step ensures that the sheaf has a neat, uniform finish. Once the sheaves (many are required) have been prepared, they can then be positioned on the roof.

The layering of the thatch begins at the bottom of the roof, where it is secured to the framework – or a turf substrate (foundation) running over the framework – with wooden or metal rods called sways. Once this base is in place, layering of the thatch begins proper, with hazel rods, referred to as spars, used to peg sheaves into position up the roof. The positioning of the spars and layering of the thatch ultimately determines the quality of waterproofing and the roof's life span.

The type of thatching material varies in both price and longevity too, with straw roofs typically lasting between 20 and 30 years, and reed lasting 30-60 dependent on type. Long straw is cut in the field with a binder and then threshed in a drum,



and when applied to a house, typically requires a thickness of 40 centimetres (16 inches) to be effective. Reeds, on the other hand, are more robust and so are layered onto a building with a thickness of around 30 centimetres (12 inches).

Historically thatched roofs were associated with working-class housing, due to the abundance of wheat and free natural materials in rural areas. Today, however, thatched properties are typically far more expensive than slate-based equivalents due to the great drop in professional thatchers available, the limited quantities of cheap thatching materials and the higher-than-average maintenance costs.

"Hazel rods, referred to as spars, are used to peg sheaves into position"

Thatching step-by-step

Take a look inside a traditional 19th-century Irish thatched cottage to see how its roof was built





"Venice's canals, which run for a total of 42km (26mi), are built and maintained in a multi-stage process"

The City of Canals's construction



HOW V was built

How was the much-loved Italian city constructed on top of marshland?



Despite Venice being frequently voted the world's most beautiful city, on paper it appears to be a logistical and constructional nightmare. It is built,

largely, on marshland - a lagoon which is just 8 per cent land, and one that contains some of the largest and heaviest religious and administrative buildings in Italy. And that's not even accounting for the dwellings of an estimated 60,000 residents and the risk (a very real risk as shown by history) of cataclysmic flooding. This, of course, raises the question: how does Venice keep above the water?

Key to its construction is an ancient method of using raised foundations, which effectively elevate ground zero to a height where buildings can be safeguarded from tidal waters. This involves the hammering of thousands of pilings - large wooden stakes commonly made from alder - through the water and into the underlying sand and clay. Each piling is positioned very closely to its neighbouring stake, one after the other, ultimately forming a raised wooden platform. Once a certain number of pilings has been driven into the earth, the tops are evened off and a substrate (or foundation layer) of wood and marble laid over the top. It is upon this which Venice's buildings are constructed.

Of course, raising buildings out of the water is but one half of building in Venice - the other being to successfully channel the lagoon's waters into commutable highways. Venice's canals, which run for a total of 42 kilometres (26 miles), are built and maintained in a multi-stage - and never-ending process that begins with the construction of a cofferdam. A cofferdam is a temporary barricade that, once erected, allows a portion of the lagoon's waters to be blocked and redirected, which is necessary for any building work to take place. Once the damming structure is in place, the draining of the area can start, with industrial pumps removing any remaining water held in the channel. Next, large-scale dredging takes place, with huge diggers and cranes excavating the channel.

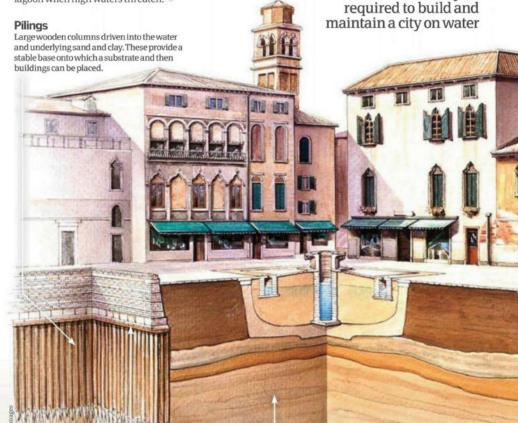
Once the channel is clear, engineers can begin fortification of the canal, utilising pilings, bricks, clay and - more frequently in recent years - cement to line and strengthen its core structure. Wooden pilings are still used today because, when submerged, the almost zero-oxygen environment of the canal preserves them incredibly well, as well as bolstering their strength further through

mineral-rich waters in their immediate vicinity. Finally, and most topically, Venice's construction is protected by a series of flood-prevention mechanisms. These range from the installation of conventional concrete dams around the city, through to a project initiated in 2003 (MOSE) to set up huge inflatable pontoons at the mouth of the

petrification - an effect caused by the flow of

lagoon when high waters threaten.

The floating city explained How It Works breaks down the materials. tools and techniques



Foundations

Venice's buildings are not placed directly onto pilings but rather a dual-layer substrate made from, firstly, planks of wood and, secondly, thick sheets of marble-the latter being water resistant.

Of course, very few buildings are built solely on pilings alone, with the Venetian Lagoon containing 117 small islands atop, or off of, which the majority of structures are assembled.

Islands

To properly install or maintain existing pilings, as well as the canal walls themselves, engineers erect temporary dams called cofferdams in order to cut off/divert water flow.

Cofferdam

Islands

Venice spans across 117 small islands in the marshy Venetian Lagoon of the Adriatic Sea. The lagoon itself stretches between the mouths of the Po and Piave rivers.

Plague

2 Between the mid-14th and early-17th control early-17th centuries, Venice was hit by the plague no less than three times, with the 'black death' claiming more than 200,000 lives.

Sinking feeling

3 In the 20th century Venice began to sink, caused largely by the digging of many artesian wells in the vicinity. As a result, artesian wells were banned in the Sixties.

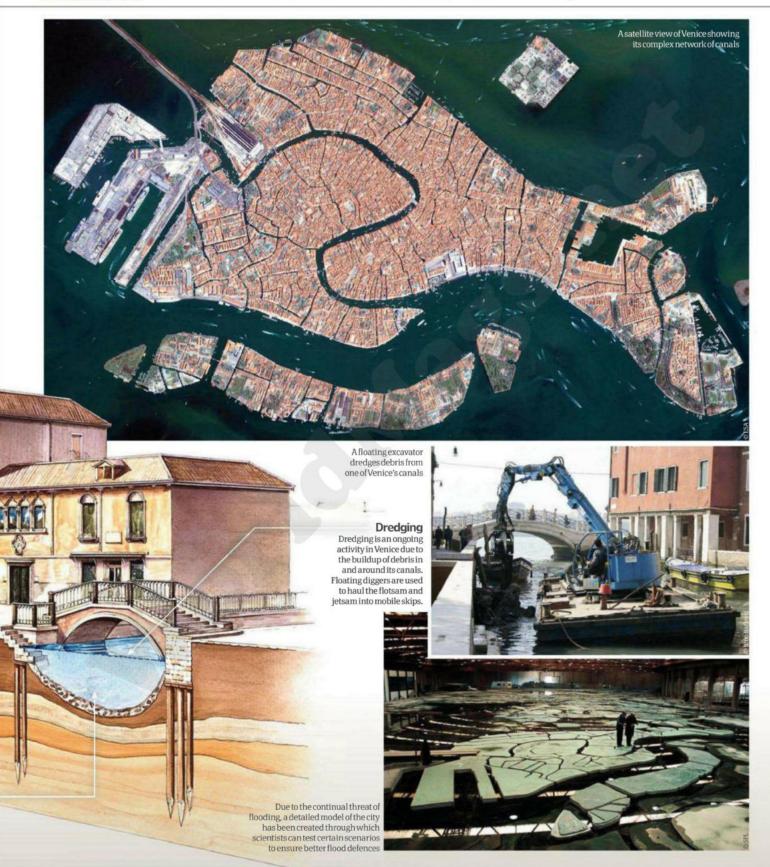
MOSE

4 In 2003 the Italian government initiated the MOSE project, which involves the creation of 79 inflatable pontoons across the entrance to the lagoon to reduce the risk of flooding.

Tourist hotspot

5 Venice is one of the most visited cities in the world, with a recent estimate stating over 50,000 tourists arrive daily. This number increases further during the famous carnival.

DIDYOUKNOW? Venice's name is derived from the ancient Veneti people of the 10th century BCE



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David Houston



David has worked at the Science Museum for nine years. When he's not talking about science, he enjoys

writing and recording music, hanging out in art galleries and watching foreign films.

Kate Mulcahy



Before working as an explainer Kate was a teacher of maths, English and physics. In her spare time she

plays rugby and likes making things such as clothes and cakes.

Andrew Brooks Science Museum explainer



Andrewisan explainer at the Science Museum. He loves drawing robots and thinking about

all the cool planets that exist across the massive universe. When not explaining he likes making as much noise as possible playing the drums.

Louise Thomas Science Museum explainer



Louise previously worked as a freelance museum educator. She has an MA in Museum Studies,

enjoys spaghetti bolognese and loves to play the not-so-talkedabout sport of ten-pin bowling.

Who built the Sphinx?

Find out on page 82

080 How It Works



■ Electricity only looks blue because we usually see electrical energy as it passes through air. Electrons in each air atom gain energy from the electricity and jump to a more excited state. As the electrons return to their original energy level they release a photon of light. In air this photon appears blue but other gases would produce different colours. For example, the gases argon, phosphor, mercury and neon are used in this way to make the various colours in 'neon' lights. **Kate Mulcahy**

> There's an absolute zero, but is there an absolute hot?

Is there a maximum temperature?

Mia McCarthy

All particles vibrate - and the more energy they have, the more they vibrate. We experience this as heat, which we measure with temperature scales. Nobody really knows if there is a maximum temperature, as it has never been reached. Some scientists suggest the Planck temperature of 1.41679 x 1032 Kelvin may be the hottest possible temperature as, according to Max Planck, above that the laws of physics stop working. However, in theory, there could be no limit to how hot something can get.

Andrew Brooks





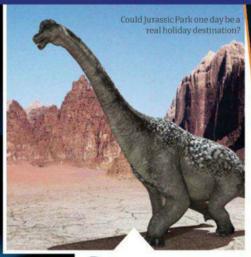


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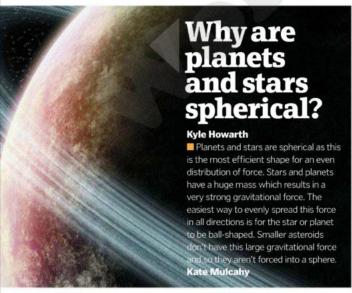


Can we clone extinct animals?

Kai Burton

Andrew Brooks

To clone an animal you must extract its DNA (genetic material) to form a cloned egg; this is then implanted in a surrogate mother. Extracting DNA from long-extinct animals, like dinosaurs, is hard as it's often damaged and incomplete. For more recently extinct animals it may be possible to find well-preserved DNA and use it to clone the animal. Scientists are now preserving DNA of endangered species, so although we have not been able to resurrect any creatures yet, one day in the future it may be possible.





EXPERT

WHO: David Houston



David has been an explainer at the Science Museum for nearly a decade. Away from science, some of his biggest hobbies are writing, art, films

What is termina

Reece Hill

If a skydiver jumped from a plane then the pull of gravity would cause them to go faster and faster as they fall. At the same time, air resistance would create a slowing force called drag. The faster the skydiver fell, the more drag they would experience. At some point their speeding-up force (gravity) and their resistance force (drag) would be exactly equal and balance each other out. This would mean that they cannot gain any more speed and this is known as terminal velocity.

Terminal velocity also applies to vehicles such as aircraft, trains and cars. There is no point having a really powerful engine if the drag is going to stop it from propelling the vehicle, hence why aerodynamics is a major design consideration.

sciencemuseum

What's on?

Hidden Heroes

WHAT: Could you be bothered to brew leaf tea five times a day or fish the beans out of your morning coffee? Hidden Heroes shines the spotlight on the overlooked inventions we couldn't live without. The inventions are presented alongside original sketches and drawings by their inventors, patent specifications and original adverts. The exhibition reveals the efforts made to establish each product, as well as sharing quirky titbits of information.

WHERE: First floor WHEN: Until 5 June 2012 PRICE: Adults: £6, Concessions: £3.50, Family: £16



Stephen Hawking: A 70th birthday celebration

WHAT: The world's most famous physicist, Stephen Hawking, is in his 70th year and, to commemorate this, the Science Museum has raided its archive to produce a display that offers an insight into his life. Objects include everything from academic notes, personal photographs, the script from the episode of The Simpsons in which he appeared, the suit he wore for his zero-gravity flight in 2007 and even a recorded message from the great man himself. WHERE: Ground floor

WHEN: Until 9 April 2012 PRICE: Free

Further information

For further information, visit the What's On section at www. sciencemuseum.org.uk.

Visit the Museum Exhibition Road, South Kensington, London, SW7 2DD. Open 10am-6pm every day. Entry is free, but charges apply for the IMAX 3D cinema, simulators and special exhibitions.



the barometer? Find out on page 84

Who invented

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Who built the

Great Sphinx?

Most Egyptologists think that the Great Sphinx was built by King Khafre (or Chephren), the builder of the second of

the pyramids at Giza who ruled around 2558-2532 BCE.

Some Egyptologists believe the Great Sphinx started out as a statue of a lion, with Khafre's features added later. This combination of man and beast represents the pharaoh's super-human power: the Sphinx suggested that the king

opposite and we'll get them answered

MANCHESTER

Campbell Price

MANCHESTER

The University of Manchester The Manchester Museum

Kate Sherburn Curatorial assista rial assistant of Natural es at The Manchester Mu



Kate works with the Zoology and Palaeontology collections at the Museum. She is

particularly interested in aquatic biology, especially sharks. She travels all over the world to see animals in their natural environment.

Bryan Sitch tor of Archaeology at Manchester Museum



Bryan has been curator of Archaeology at The Manchester Museum for five years. Before he has worked for museums in

Hull and Leeds. At the moment he's working on the Ancient Worlds display.

Campbell Price Curator of Egypt and Sudan at



Campbell is currently busy redeveloping the Ancient Worlds galleries, opening in October. He travels to

Egypt a lot to work on archaeological projects. Follow him at http:// egyptmanchester.wordpress.com.

Andrea Winn Curator of Community Exhibitions at The Manchester Museum



Andrea has been working at The Manchester Museum for four years in outreach and

engagement. She has a background in social and economic history.

How long do mummies last?

Find out on page 85



Can honey go bad?

Eve Lynch

Honey is the only food that does not go off - indeed, honey found in King Tutankhamun's tomb was still edible. It has a high sugar content and antibiotic properties that act as preservatives. Over time honey becomes cloudy as the sugar crystallises, but this does not spoil it and you can dissolve the sugar by heating it gently. If moisture gets into the honey, though, yeast can grow, ferment and spoil the foodstuff, but so long as it is kept tightly sealed honey can keep indefinitely. **Kate Sherburn**



Can an elephant jump?

As the world's largest land animal, weighing several tons, elephants are simply too heavy to jump. Their bone structure prevents them from bending their legs enough to push themselves off the ground. Elephants do not have natural predators so they did not need to be able to jump to improve their chances of survival, Elephants do not even like standing on two legs, although they can be trained to do so.

Kate Sherburn

getting ready to

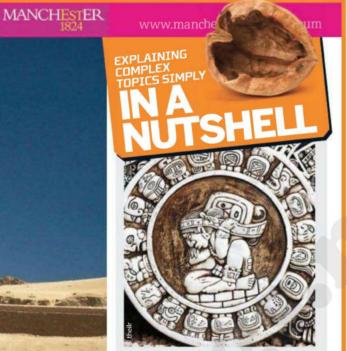
jump... or not





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Katherine Cooke

Did you ever have a spirograph? The toy had different plastic wheels that meshed with one another and revolved like a clock mechanism. You had to insert a pen and move it round the wheel to create a series of increasingly complicated circular designs on a sheet of paper beneath. The Mayan calendar worked in a similar way.

The first cycle in the Mayan calendar had 13 numerals and the second wheel had 20 named days. The two wheels revolved like a cogged mechanism, so it would be 260 days before the same point was reached again as the two circles rotated. This was then meshed with a third wheel of 365 days (known as the 'vaque year'), but of 18 months instead of our 12. Each month lasted 20 days with a 'filler' month of five days.

The Mayans appear not to have worried about the extra quarter day (that's why it was a 'vague year'). We do allow for this and that is why every four years we have a leap year (2012 is one), in order to keep our calendar in sync with the movement of the Earth around the Sun.

The Mayan cycles would give a calendar of 18,980 days, or 52 years. For longer time spans there was the 'long count' with a unit of measurement called the bak'tun of 144,000 days. 13 of these bak'tun have passed since the cycle started in 3114 BCE and it ends later this year on 23 December - 1,872,000 days later!

People have speculated the end of this period of time will be marked by a terrible cataclysm that will wipe out the human race. As the Mayan calendar projects dates of anniversaries well into the future (long after 2012), I for one intend to sit back, not do anything rash and see what happens. **Bryan Sitch**



What are fleas?

Toby Connor

Fleas are small (2-3 millimetre/ 0.08-0.1-inch) red-brown wingless insects that feed on the blood of mammals and birds. They are compressed side to side so that they can move through fur and feathers easily and have long legs that let

them jump 100 times their height. They can survive for months without food and their young can live in our carpets and bedding. Flea bites are itchy and can cause allergic reactions. Fleas can also carry diseases such as bubonic plague and myxomatosis.

Kate Sherburn

MANCHESTER

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What's on?

Unearthed: Ancient Egypt

WHAT: 100 years ago, many archaeologists carried out huge digs in Egypt, unearthing ancient objects such as toys, farming tools, stone carvings and burial goods. These discoveries give us an idea of what life was like for the Ancient Egyptians, from their home life and work to their language and beliefs. Travel back to the Twenties and enter the storeroom of our period Egyptologist, played on film by Terry Deary, author of Horrible Histories and Egyptian Tales.

WHERE: The Manchester Museum, Floor G Temp Exhibitions space WHEN: Until 6 September 2012

PRICE: Free

The Museum Allotment

WHAT: See what's growing on our allotment. The allotment has been inspired by the Museum's new Living Worlds gallery which explores the connections between all living things, including us, and shows how we can all shape the future by the choices we make (such as growing our own food). WHERE: Located outside The Manchester Museum WHEN: Until autumn 2012

PRICE: Free

Tours of the Vivarium (live animals)

WHAT: Zoology students from The University of Manchester will share their knowledge of the animals and highlight the conservation and education work that both the Museum and University do. Monthly tours run in Spanish and French.

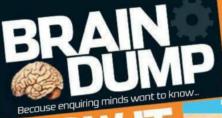
WHERE: The Manchester Museum WHEN: Every Tuesday and Thursday,

PRICE: Free, but you must call beforehand to book a place

Further information

For further information, visit the What's On section at www. manchester.ac.uk/museum.

Visit the Museum The Manchester Museum, The University of Manchester, Oxford Road, Manchester, M13 9PL museum@manchester.ac.uk



Tube station?

Find out on page 86

What's the busiest Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

roudly associated with National Museums Scotland



National Museums Scotland

Alison Morrison-Low



Alison is responsible for the collections of historic scientific instruments and photography. Her

research interests include the evolution of scientific instruments. the history of the collections and Scottish photography.

arah Stewart



Sarah is responsible for the curation of the invertebrate fossil and plant collections -particularly the

molluscs and more problematic fossils. Her research focuses on fauna from the Silurian and Ordovician periods.

Aidan Dodson Advisor for Fascinating Mummie



Aidan teaches Egyptology at the University of Bristol and is the advisor for the Fascinating

Mummies exhibition, which is running at the National Museum of Scotland until 27 May 2012.

Tacye Phillipson

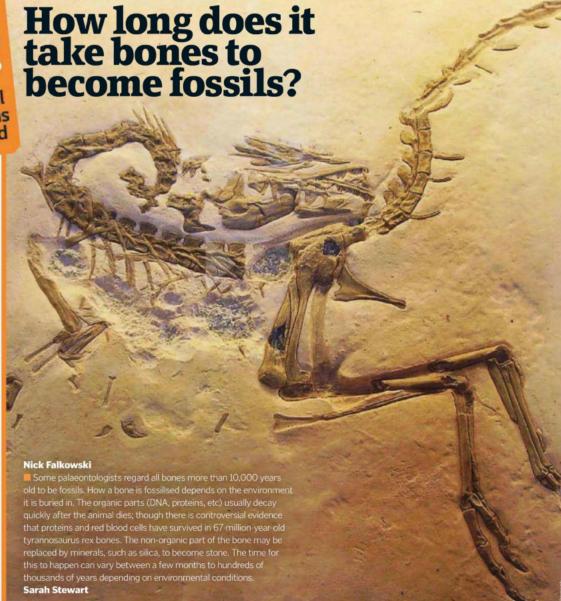


Tacye has a PhD in Physics and is now senior curator of Modern Science at NMS. Her job

involves everything from artificial arms and astronomy to space rockets and zoetropes.

What is a hybrid bus?

Find out on page 87



Who invented the barometer?

Stuart Thomas

Evangelista Torricelli became court scientist to the Duke of Tuscany in 1642. He experimented with fountains in Florence and a long tube over ten metres (33 feet) high filled with water that was in his house. In 1644 Torricelli described how he took a glass tube about one metre (3.3 feet) long, sealed at one end, and completely filled it with mercury, which is much denser than water. Then, holding his finger over the open end of the tube, he inverted it under the mercury contained in a large bowl and removed his finger. The mercury fell to a height of about 76 centimetres (30 inches) above the mercury level in the bowl and stayed there. This is still called Torricelli's experiment and the space at the top of the tube above the mercury in barometers is known as the Torricellian vacuum.

Alison Morrison-Low







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www.howitworksdaily.com

National Museums Scotland

How many years can mummies last?

Mike Murphy

A mummy is a body from which most of the moisture has been removed by the use of a mixture of salts known as natron, after the valley in Egypt where it is found, and then wrapped in linen bandages. If kept dry, it can then last for ever - many

have been found in perfect condition after up to 4,000 years. However, if they get damp, they can rot down to bare bones which happened to the pharaoh Psusennes I, in spite of his tomb never having been touched by robbers.

Aidan Dodson



What's the USA's biggest road?

Spanning a whopping 5.415 kilometres (3.365 miles), the US Route 20 is the longest road in America. The US 20 runs east to west from Boston, Massachusetts. at Kenmore Square, right through to Newport, Oregon, where it merges at an intersection with US Route 101 just a mile from the Pacific Ocean. Interestingly, the route passes by the famous Yellowstone National Park and, up until 1940, this is where the road terminated.







Who was the longest-serving pharaoh of Egypt?

According to later king lists, Pepi II ruled for 94 years around 2200 BCE. However, contemporary documents only go up to the seventh decade of his reign, and it is not certain that he really ruled for that long. The longest fully documented reign is the 67 years of Rameses II, who came to the throne in 1279 BCE and built more temples than any other pharaoh. The next place is a tie between Thutmose III (1479 BCE) and Psamtik I (664 BCE), both of whom ruled for 54 years. Aidan Dodson



Do carrots help you see in the dark?

Leanne Attwill

This myth isn't quite true, but the story of how it came about is quite interesting. First of all, carrots are rich in vitamin A, which itself has been linked with many health benefits. However, various tests and studies have conclusively proved that eating carrots will not improve your eyesight if it is already good. That being said, if you have a vitamin-A deficiency then it is likely that eating carrots will improve your night vision.

The origin of this myth stems from WWII. During the war Britain developed a new way to determine the location of Nazi bombers before they reached England, known as airborne interception (AI) radar. However, not wanting to alert the enemy to their new technology, the British government released various pieces of propaganda through the Ministry of Food stating that the new detection method was the result of pilots eating more carrots and being able to see the bombers more clearly in the dark. As well as fooling the Nazis, this story also encouraged British people to grow and eat more vegetables at a time when other goods such as meat were scarce due to rationing.





True 🖊 False



What's on?

Reconstructing Lives

WHAT: Many have lost limbs as a

result of war and it takes a lot of strength to get back on track. The medical field has strived to ease this process with prosthetic limbs - the focus of this evocative exhibition. See how they have developed over the centuries from metal hands to cutting-edge bionic limbs. WHERE: National War Museum, Edinburgh Castle WHEN: 9 March 2012-February 2013 PRICE: Free, with admission

See Scotland by Train

to the Castle

WHAT: Over 30 striking posters give a flavour of what it meant to travel by rail over the past century. The posters depict some of the most scenic locations in Scotland and are works of art in their own right. See Scotland by Train will follow the changes in styles of railway art over the last 120 years, also showing how rail travel in the country has evolved. WHERE: Exhibition Gallery 2, Level 3, National Museum of Scotland, Edinburgh WHEN: 16 March-24 June 2012 PRICE: Free

Fascinating Mummies

WHAT: Ancient Egypt is a common theme at British museums and perennially popular, which just goes to prove one thing: we can't get enough of mummies! As well as the super-preserved stars, a host of tech helps bring the Egypt of yore to life. WHERE: Exhibition Gallery 1, Level 3, National Museum of Scotland, Edinburgh WHEN: Until 27 May 2012 PRICE: Adults: £9, Concs: £7.50, Children: £6, Members: Free

Further information

For further information, visit the What's On section at

Visit the Museum

National Museum of Scotland,
Chambers Street, Edinburgh, EH11JF.
Open daily 10am-5pm, including
Sundays and bank holidays, but
closed 25-26 December and hours are
12-5pm 1-2 January. Entry is free.



Horse buses and trams explained

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered



Caroline Warhurst



Caroline is responsible for ensuring that the Library collection at the Museum is looked after and that all enquiries

sent to the LTM are answered accurately. She also helps colleagues from Transport for London, designers and students with historical research.

What's on?

Sense and the City

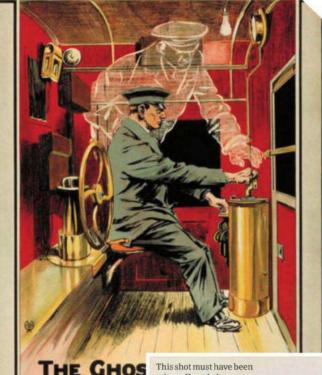
WHAT: Love it or hate it, emerging technologies are transforming the way we live, work and play in our cities. London Transport Museum's special exhibition, Sense and the City, unravels the digital future and compares this with past visions of the future. Plus a new poster display -Painting by Numbers - complements the exhibition by showing historical versions of data visualisation infographic posters at their best. WHERE: London Transport Museum WHEN: The exhibition and the poster display close on 18 March 2012 PRICE: Adults: £13.50, Concessions: £10 - allows unlimited entry for a whole year, Children: Free

Depot Open Weekend

WHAT: A rare opportunity to visit London Transport Museum's store in Acton, West London, It houses over 370,000 objects including road and rail vehicles, engineering drawings, signs, ephemera, posters and artwork. Highlights include curator-led tours of

When did taxis first get meters?

Find out on page 87



What is the dead man's handle?

Simon Andrews

The 'dead man's handle' was designed to act in the event of a driver falling ill while on duty. With the introduction of electricity on the railways at the end of the 19th century the fireman was no longer needed, so the driver worked alone in the cab. The Ghostly Driver poster (1912, pictured) highlighted the alerting device, which consisted of a flat knob on top of the controller handle. This was supported by a spring weak enough to be held down without effort by the driver's hand when operating the controller handle. As long as the driver kept the knob down, the controller operated normally. If pressure was released for any reason (ie if the driver became unwell and lifted his hand) the current was immediately cut off and the brakes were applied. The device is still used today, but is more commonly called a vigilance device.

Caroline Warhurst

THE GHOS

READ ALL ABOUT HIM AND LONDON'S TRAFFIC IN THE ST

IN THE JUN

Which is the **busiest Tube** station on the London **Underground?**

James Rafferty

During the three-hour morning peak, London's busiest Tube station is Waterloo, with 57,000 people entering. The busiest station in terms of passengers each year is also Waterloo with 82 million. The original Tube station was opened in 1898 by the Waterloo & City Railway, which was not at that time part of the Underground. The Baker Street & Waterloo Railway operated its services there from 1906. It soon adopted its popular nickname, the 'Bakerloo' line, which persists to this day.

Caroline Warhurst







howitworks@imagine-publishing.co.uk



→103969

When were travelcards first introduced in London?

Travelcards were introduced in 1983 and transformed attitudes to public transport in London, Passengers no longer had to have separate tickets for each part of the journey and, for the first time, the same ticket could be used on buses and the Underground across three zones (Central, Inner and Outer). By 1985 some 800,000 were in use. Today there are nine zones and Oyster cards account for millions of

journeys. When Oyster pay-as-you-go was extended to all 350 National Rail stations in Greater London in 2010 it doubled the number of stations where Oyster was accepted, allowing it to be used on all National Rail, Tube, DLR, London Overground, London Buses, Tramlink services and Thames Clipper river services. By 2011, Oyster customers had made over 80 million rail journeys in 13 months.

Caroline Warhurst

When did taxis first run on meters?

Tim Early

Weekly

Taxi meters were made compulsory in motor cabs in July 1907 although a simple device to measure distance was used experimentally as early as 1847. Before meters became obligatory, resistance to any kind of regulation was fierce and overcharging was common. Once they became compulsory in motor cabs though, many horse-cab owners adopted them in order to compete for customers, even though they weren't required to have them. There were only 723 motor cabs on the streets of London in 1907 - hugely outnumbered by 9,789 horse cabs. However, by 1910 the position had reversed with a total of 6,397 motor cabs on the road compared to only 4.724 horse cabs.

Caroline Warhurst

Taxi meters have been a legal requirement since 1907





What is a hybrid bus?

Kimberley Bexon

Hybrid buses are an eco-friendly form of public transport. They are quieter, cleaner and more fuel-efficient than standard diesel buses. Hybrid buses reduce emissions of local pollutants and carbon dioxide by at least 30 per cent compared to conventional buses. The main thing that differentiates hybrid buses is that they

combine a standard engine and an electric motor so that, overall, they consume less fuel. The hybrid buses in London also have regenerative braking, which means they produce electrical energy whenever the brakes are engaged. This energy is stored in a battery pack and used to power the motor, making them highly efficient.

Caroline Warhurst

What were horse trams and buses?

Fiona Ryan

Horse buses were pulled by two horses and carried up to 26 passengers. Horse trams were bigger and had metal wheels. which ran on smooth tracks in the road making them much easier to pull. Two horses could pull a tram carrying 50 passengers - twice as many as buses. Being able to carry more passengers than a bus with the same number of horses made trams cheaper to run, helping to bring public transport within the reach of ordinary working people for the first time.

Caroline Warhurst





the small object store, rides on the Depot's miniature railway and trips on heritage vehicles. This year, the theme of the weekend is London's Transport in Miniature, which will feature working transport model layouts displayed in various sizes. WHERE: The Museum Depot. 2 Museum Way, 118-120 Gunnersbury Lane, London, W39BQ WHEN: Saturday and Sunday 10-11 March 2012, 10am-5pm PRICE: Tickets valid for both days. Adults: £10, Senior citizens: £8, Concessions: £6.50, Under 16s: Free

Mind the Map: Inspiring art, design and cartography

WHAT: With everything from early hand-drawn maps to brand-new digital examples, this major exhibition will reveal how the field of cartography has evolved over the centuries. One of its main aims is to show how maps are not just a means of navigation but an excellent way to express creativity and artistic flair. WHERE: London Transport Museum WHEN: 18 May-28 October 2012 PRICE: Free

Artists' showcase: Play and the City

WHAT: Mobile devices and social media are having a dramatic impact on the way we use our city. Technology designed for navigation and communication purposes is being subverted by artists and gamers who seek alternative urban adventures. During the evening artists will share how mobile and social-networking tools can transform a city into an interactive playground. Produced in partnership with digital arts group onedotzero. WHERE: London Transport Museum WHEN: Friday 16 March 2012, 6.30-8.30pm

PRICE: Adults: £9, Concessions: £7 (includes a complimentary drink)

Further information

Further information about events and exhibitions at www.ltmuseum. co.uk. To book in advance call 020 7565 7298.

Visit the Museum London Transport Museum, Covent Garden Piazza, London, WC2E 7BB. Open daily. Adult admission charged and allows entry for a whole year.

GAMES · BOOKS · GADGETS · TOYS CONNOISSEURS of kit and savants of stuff

Archos 35 Home Connect Internet Radio

Price: £120/\$130

Get it from: www.archos.com

The 35 Home Connect is both an impressive internet radio and an alarm clock. It comes with a program called Tuneln Pro, which will find all the stations you want to listen to. The speakers are great for such a small device and setting up is a breeze. However, we did have a couple of issues. For one, it's very bright, and if you plan to use it as a bedside alarm clock then you might have some trouble sleeping. The touchscreen controls are also pretty poor, with scrolling motions especially hard to execute. As far as basic web radios go, however, it's more than adequate, and with a low price to boot you won't be disappointed.

Pros:

Simple setup
Good speakers
Cons:
Screen is too bright
Poor touchscreen

Pros:

Easy to use

Excellent audio

Cons:

SONY

Samsung MV800

Price: £200/\$280

Get it from: www.samsung.com

While it might not boast some of the advanced features of similarly priced cameras, the MV800 is a great fun compact that has enough on offer to warrant serious consideration. The standout design feature is the 7.6-centimetre (three-inch) touchscreen that can be flipped 180 degrees; this allows you to stand the camera at an angle or easily take self-portrait or group shots. The smartphone-like software uses a tiled app UI to keep the menus clean and simple to navigate, making the camera incredibly easy to use. The 16.1MP sensor and 5x optical zoom also ensure you'll get high-quality images whether you're shooting in low or high light. The camera boasts a ton of both silly and serious shooting modes, from a funny face option to standard panoramic shots. Overall it's a nifty little camera and its small size ensures you'll be able to carry it about in your pocket without hardly noticing it's there.

Sony SRS-BTV25

Price: £149/\$235

MY TOURIST

NO EEVON

Get it from: www.sony.co.uk

This Bluetooth speaker oozes style, boasting both a super-sleek exterior and a hardy technical interior. Inside are two audio sources: a standard 20-millimetre (0.8-inch) speaker and a 56-millimetre (2.2-inch) woofer. The unique design projects sound in 360 degrees, ensuring that the whole room hears the rich sound. And rich it is, as the addition of a bass boost button raises the meatiness of the audio, giving an excellent listening experience. Any external music device can be connected to the speaker by either the Audio-In jack or Bluetooth, provided the device has it. An additional USB socket lets you charge your device while it plays music. This is an excellent product, and while it's a bit on the pricey side, it's perfect for all your portable audio needs.



Fun to use

Simple

Limited

Colourful diagrams Accurate information

HOWIT

My Tourist Guide To The Solar System And Beyond

Get it from: www.dk.co.uk

This book from DK is an excellent beginners' guide to astronomy, providing detailed illustrations and information on a whole host of cosmic phenomena. From the surface of Mars to black holes, the text and images convey the wonders of space in a manner that young children will be able to understand and enjoy. By the same token, most of the information on offer, while accurate, is rather simplistic. You won't find in-depth analyses on any of the topics, but you will find basic facts that will at the very least give you a hunger for more. With that in mind this book is probably only suitable for younger readers but, nevertheless, it's still an excellent account of our solar system and beyond.



ASUS N55SF

Price: £750/\$1,300

Get it from: www.asus.com

This powerful laptop is the ideal desktop replacement on the inside, while its lightweight and minimal exterior also rivals most laptops around right now. Its price is aimed at the mid-range market but what's inside is anything but average as the powerful Core i7-2570QM processor makes this a very fast and impressive bit of kit. Included is also a Blu-ray drive and a top-of-the-range NVIDIA GeForce GT 555M graphics card, making this the ultimate entertainment laptop for gamers and movie-watchers alike. The chassis of the N55SF itself also looks great, with a deliciously sleek style ensuring this won't look out of place in any home or office. Our only grievance was the inbuilt speakers, which are a little weak when it comes to pumping out louder audio. However, this powerhouse of a laptop comes with a reasonable price tag and we'd be hard pressed not to recommend it.



A new take on maths

A little slow to get started

Hailo - The

Version: 1.4.1 / Size: 6MB / Rated: 4+

HAIL

If you've ever stood in the middle of a London street trying to grab a taxi, you'll know how difficult it can be, but Hailo is here to help.

will display the nearest cabs, as well as an approximate wait time. To call a taxi, simply tap the 'Pick me up here' button.

Verdict: 00000

www.knowyourapps.com



17 Equations That Changed The World

Get it from: www.profilebooks.com

The title might not be the most appealing, but if you've ever wondered how maths is integrated into our everyday lives you'd be well worth checking this book out. Although text heavy and devoid of many diagrams, it makes for a fascinating insight that even those with just a basic understanding of arithmetic will enjoy. In addition to explaining complex topics, Professor Stewart successfully integrates just the right amount of history and modern-day exploits, giving the reader an overview of how important various equations are to us today. Once you get through the initial chapters, you'll unearth a brilliant read.

Brought to you by Apps Magazine, your essential guide to the best iPhone and iPad apps available on the Apple App Store

iPad

Smoovie

Price: £2.99/\$4.99

Developer:

Open Planet Software

Version: 1.0 / Size: 11.4MB / Rated: 4+



Smoovie makes stop-motion films easy. While you still need to take individual photos with an iPad 2, doing so is made simpler

thanks to the huge number of stands that fit the tablet. Scenes can be reordered so you don't have to shoot everything in sequence and you can also add music from your library.

Verdict: 00000

Skeleton System Pro III

Price: £10.49/\$14.99 Developer: 3D4Medical.com Version: 3.0 / Size: 509MB / Rated: 4+



Using a host of multitouch gestures Skeleton System Pro III guides you through the intricate design of the human skeleton. If

this app is a glimpse at the tech medical professionals will be using in years to come then it will make any visit to a hospital or medical centre a very interesting experience!

Verdict: 00000

iPhone

Black Cab App

Developer: Hailo Network Ltd



Your location will be pinned to a map and Hailo

You can get daily app feeds by checking out



KNOWLEDGE COUP TEST



Action cameras We put three all-purpose video recorders to the test



Replay XD1080

Price: £300/\$450

Get it from: www.purelygadgets.com

If you're looking for a small and easy-to-use camera that can record HD video in a variety of situations, then the Replay XD1080 is a great choice. The camera itself is a cylindrical design that can attach onto a bike, helmet or other objects with either the included mounting device or the sticky pad. The camera records in 1080p through 115 degrees, making video quality excellent, although the microphone does pick up a bit too much wind at times. As you move from low to high light the camera does also slightly oversaturate, but for the most part you won't have a problem. The stand included with the set is adequate, if a tad small, allowing the camera to be rotated up and down and side to side but not by a huge amount. However, the simple interface is where this camera excels. On the top are two buttons and these are used to power the device and start/stop video recording, with a vibration that can be felt through a helmet letting you know your button-press has been registered, making it very practical when your hands are occupied. This is a light and well-constructed all-purpose camera for biking, skiing and any other times where you could do with a functional snap-on camera.

Verdict: 0000

GoPro HD Motorsports HERO

Price: £240/\$375

Get it from: www.purelygadgets.com

In the world of versatility, the GoPro HD is king. Boasting a variety of mounts, a waterproof casing and exceptional image quality, the Motorsports HERO edition will handle almost any high-octane situation that you throw at it. Unlike the Replay the camera uses a basic display to sift through menus, which can at times be hard to read but otherwise does its job. You've got the option of recording in 1080p and 30 or 60 frames per second, while the wide-angle lens does a great job of capturing the action, ranging from 170 degrees for standard video to 127 degrees for 1080p. The mounting options are varied with chest, head, bike and handlebar mounts all available. The built-in microphone handles sound better than the Replay XD1080, although we found the camera in general a little trickier to use while out and about. The protective casing is a well-conceived addition for keeping the GoPro safe but it's not the best fit, so you might get a bit of wobbling. Overall, though, this is an excellent recorder that will enable you to capture high-quality video in all kinds of action-packed scenarios.

Verdict: 00000

ContourHD 1080p Full HD Helmet Camera

Price: £140/\$220

Get it from: www.purelygadgets.com

For rugged outdoor activities like paintballing, the ContourHD is the perfect companion. This small camera is incredibly tough, meaning it'll handle bumps and scrapes and still provide exceptional 1080p video. It boasts all the bells and whistles of the other cameras in our test including a microSD slot, LED activation lights and a USB port. The camera itself is very simple to use, and when wearing gloves it's easier to get stopped and started than the Replay or GoPro - just move the sliding bar at the top of the device to begin and stop recording. The wide-angle 135-degree lens can be rotated through 180 degrees, allowing you to get the optimal viewing angle. The image quality is good, if just surpassed by the other two products, but unfortunately the out-of-the-box sound quality isn't the best, so it won't handle highspeed excursions too well. However, this is an incredibly easy-to-operate camera designed for fast and jerky movements, so if you're planning to use it for on-foot outdoor activities it's probably the best pick. It also has a nice low price tag, so bargain hunters should be happy!

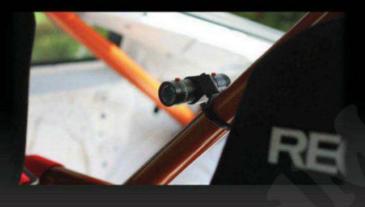
Verdict: 0000

PL XD1080

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The world's smallest action camera





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- Water resistant
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HOME EXPERIMENT Make an elastic band racer

RUBBER BAND RACING CAR

Create your own DIY racing car from just a few everyday household items

Equipment:

1 x cardboard tube

1 x sheet of coloured card/paper

1 x rubber band

1 x stickytape

2 x pencil

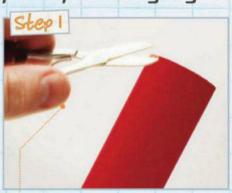
1 x glue

1 x craftknife/ scissors

1 x paperclip

4x bottle top (identical)

1 x ruler



STEP 1. Take your cardboard tube and cut it to your desired length. Your racer can be any size, but the longer its body the stronger the elastic band you'll need; a length of 15-20 centimetres (six to eight inches) is ideal, unless you have some industrial-strength elastic in your house! Carefully cut the tube either with scissors or a craft knife on a stable, protected surface.



STEP 2. With your cut-down tube in hand, mark two pairs of level points about five centimetres (two inches) from each end. We'll use these as a guide to place our wheel rod slots. The rods are your pencils, so any hole will need to be slightly larger than their width. Once the points are drawn, take your cutting instrument and, with care, puncture the tube.



STEP 3. Put aside the tube and measure a pencil, scoring it at a length where it will extrude from either side of the tube. This will ensure there is plenty of clearance for the wheels, which will go on the ends later. Cut the pencil down and then repeat this step with the other. Once both pencils have been trimmed, slot them through the holes in the toilet roll.



step 4. Now we need to create another hole running vertically through the tube two centimetres (o.8 inches) behind the forward axle; this is for a fixed rod to attach our elastic band. Follow the steps used to create the wheel axles, except this pair of holes must not leave any room for the rod to move, so make sure the rod (a remaining piece of pencil) fits snugly.



STEP 5. Take your elastic band, slot the fixed vertical rod through it within the tube and then glue the rod in place so the band is stuck. Now unwind your paperclip and use it to hook the band towards the rear of the racer. As with the fixed rod, thread the rear rod through the band and replace it into its holes. The band should now be taut between the two rods.

and snap them in place on the axles. Then place the racer on an even surface, pull it back and release. If you have constructed it correctly the car should shoot off. Make a few and race them!

WHY NOT TRY... ecorate your racer wit

coloured card, paper or paints – or why not increase the number of rubber bands to boost the power output?

GET IN TOUCH!

If you have a go at our experiment either at home or at school, remember to send us some pics to **howitworks@imagine-publishing.co.uk** so we can see how you got on.

TEST YOUR STAND WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ HASED ON THIS MONTH'S CONTENT?

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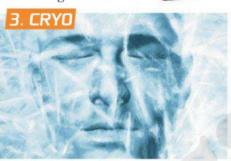


Q: What is the largest moon in our solar system?

Α:



Q: Which unit is a mobile phone's signal strength measured in?



Q: What is the coldest recorded temperature on Earth?



Q: Roughly how many species of venomous snake are there?



Q: What is the maximum degree that an owl can rotate its head?



Q: Which type of decoy flare is activated upon contact with air?



Q: Which was the first spacecraft to 'touch down' on another planet?



Q: What is the longest-lasting type of thatching material?



Q: Which ancient people is the city of Venice named after?



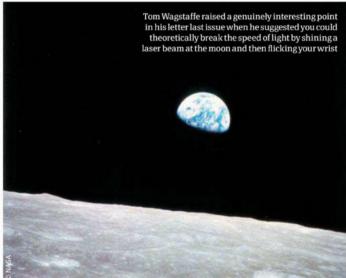
Q: How much horsepower can a Ford Fiesta RS WRC car produce?





Get in touch!

We enjoy reading your comments every month. So keep us entertained by sending in your questions for the mag, comments on what you like/don't like, any science-related news you want to share, or just say hello...



Apologies to Tom

HIW: We'd like to apologise to Tom Wagstaffe, Last issue (30), in an attempt to respond to his letter 'Laser speed' in a humorous manner, we misunderstood the question and were a bit abrupt in our reply. Tom, you are indeed correct in suggesting that shining a laser on the moon from Earth and moving it on the ground would appear to make it move a great distance on the moon in a short space of time - seemingly faster than light. Unfortunately, though, this is merely an illusion. It's not the same dot travelling across the moon, but rather different photons at each point reaching your eye. This 'faster than light' illusion is also prevalent in pulsars, which fire out jets of energy in vertical directions that can appear to travel above light speed due to the distances involved as they sweep around. We're very sorry for getting the wrong end of the stick, but we hope that we've now helped to

Make your own spectroscope

explain this phenomenon sufficiently.

Good afternoon, I am trying to make a spectroscope as outlined in your recent magazine. Please can you tell me where I can obtain transparent CDs. All the ones I have are printed on one side.

Mrs C Watson (physics technician)

HIW: A few people have asked the same question. Our transparent CD came from a stack of regular discs. There is usually a transparent disc either on the top or bottom of the set. While this means you'll need to purchase a stack of CDs, you can get a box of ten for just a few pounds.

Oh, man!

I bought the first issue of HIW two years ago when I was abroad, living in Oman, and I absolutely loved it as I love, well, how things work! I was so happy that someone had brought out a magazine that is almost tailored to my passion. I downloaded the app for iPhone and thought I'd wait until I got an iPad to read the rest, since I thought an iPad would be better for viewing a mag like this. However, two years later, guess what I got? An iPad 2. I am now racing my way through the series, catching up on what I missed. Thanks for publishing such a brilliant magazine.

Edd Hulston

Is anyone there?

I have no doubt that there is life out there. There are billions of stars in our galaxy and there are billions of galaxies beyond ours in the universe - the closest being Andromeda, which you can actually see close to the Cassiopeia constellation. But I think ET is most definitely out there. The conditions for life are so specific that the chances of it are extremely minute, like looking for an orange and yellowtinged grain of sand on a beach. But, if it happened here, why not anywhere else? Whether it is intelligent or not is the real question. As you may or may not know, we have been sending signals (I believe in the form of music and speeches) into space for years. What's funny is that if those signals have reached a planet with life that's not intelligent, it would go unheard. But if it is intelligent, then there



Letter of the Month

Thyme for answers

I was very interested to read your article on the differences between fruit and vegetables in issue 30. However, it got me thinking as to what exactly herbs are. Is a herb a vegetable or a fruit – or neither? I was under the impression that herbs can be considered as either herbs or vegetables, but that all vegetables are considered as herbs. Is this true? Alan Pooley

HIW: It all gets a bit complicated to be honest, Alan, but you're

pretty much correct. It is often said that everything can basically be classified as an animal, mineral or vegetable, so under this classification herbs are considered vegetables.

However, to be more specific, in horticultural terms herbs are said to be herbaceous plants that have some kind of purpose (whether that's medicinal, edible or otherwise), while vegetables are those that are solely suitable for consumption.

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could be a reply on the way. This is very unlikely though. What's more likely is that when our signal reaches a planet with intelligence, they send one back. And the time it takes for all this to happen, we have destroyed ourselves or something else has. But we can dream...

BoothyLad

HIW: We'd be surprised if microbial life, or signs of past life, are not one day discovered on Mars, Titan, Europa or one of the other potentially life-harbouring planets and moons in the solar system. We've long been sending out signals and messages to potential alien races. For example, the Voyager and Pioneer probes both carry plaques (see photo right) with information like our position relative to nearby pulsars plus images and sounds from Earth. In addition, an intense radio beam known as the Arecibo message containing data about Earth was sent out in the direction of a globular star cluster 25,000 light years away, while any intelligent aliens listening in the

one of the many other radio signals emitted from our planet. Whether we'll hear anything back in our lifetime is another matter.

Those who can...

I'm 15 and in my GCSE years. I've noticed that a lot of the Science section is relevant to my biology course and I find it a very useful revision tool. I hate biology mainly because of my teacher, but I found your article on DNA structure in issue 28 very interesting - I finally understand it. I don't suppose you could do an article on the central nervous system and the reflex arc? My teacher really is hopeless!

Edward

HIW: We didn't print your full name, Edward, in case you get in trouble! Glad we could help with your studies.



What's happening on...

This month we asked you guys to submit your own queries for our 'Secrets of the universe' feature (over on page 13). However, not all of your questions made the cut, so here's the best of the rest. Do you know any of the answers?

☑ vesprl1

@HowItWorksmag Has the order of the planets in the solar system always been the same?

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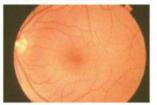
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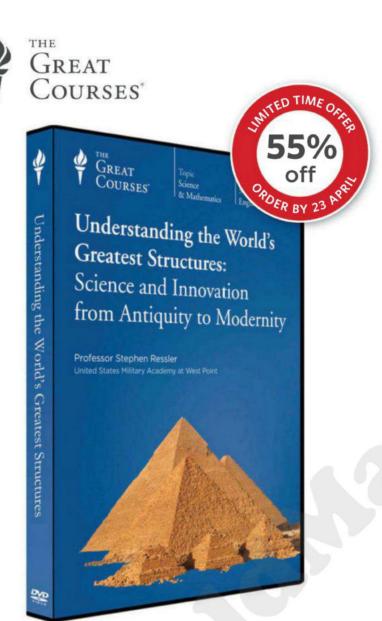


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